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Gas Journal

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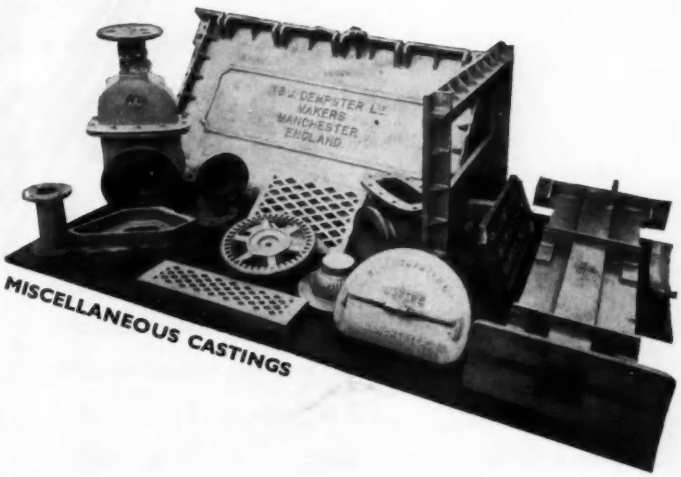

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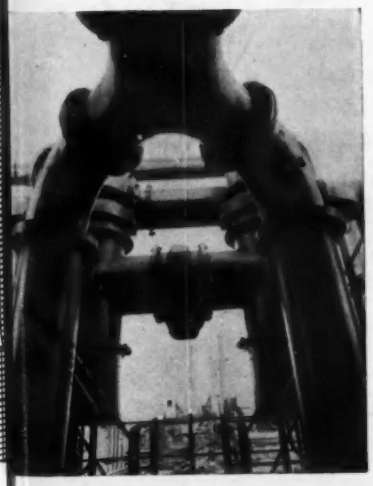

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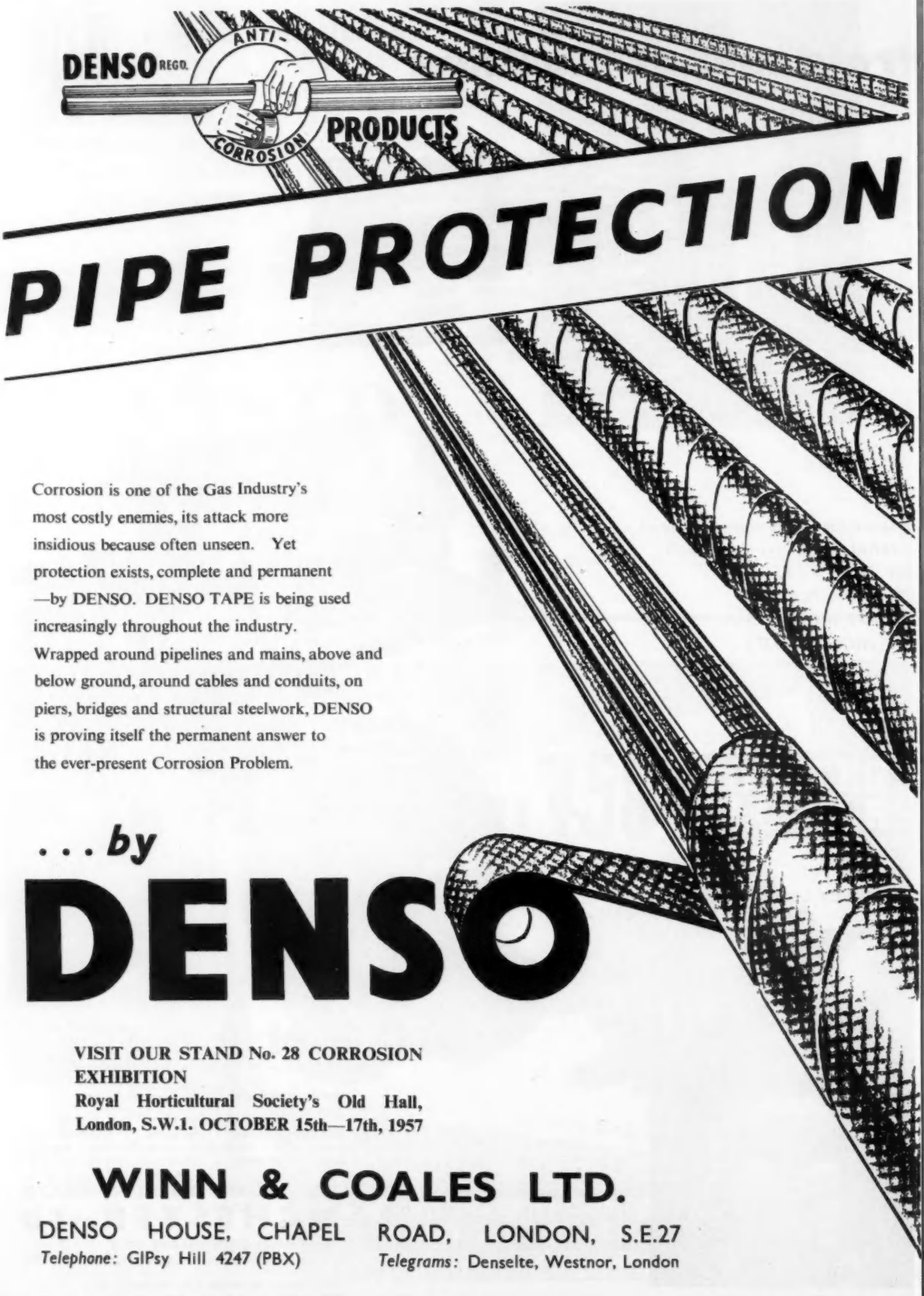

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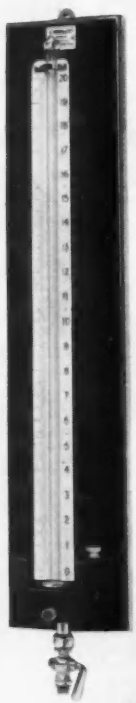

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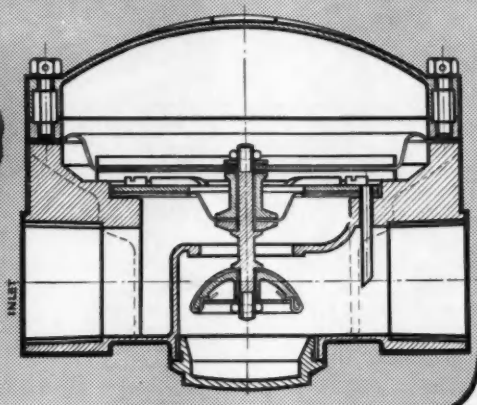

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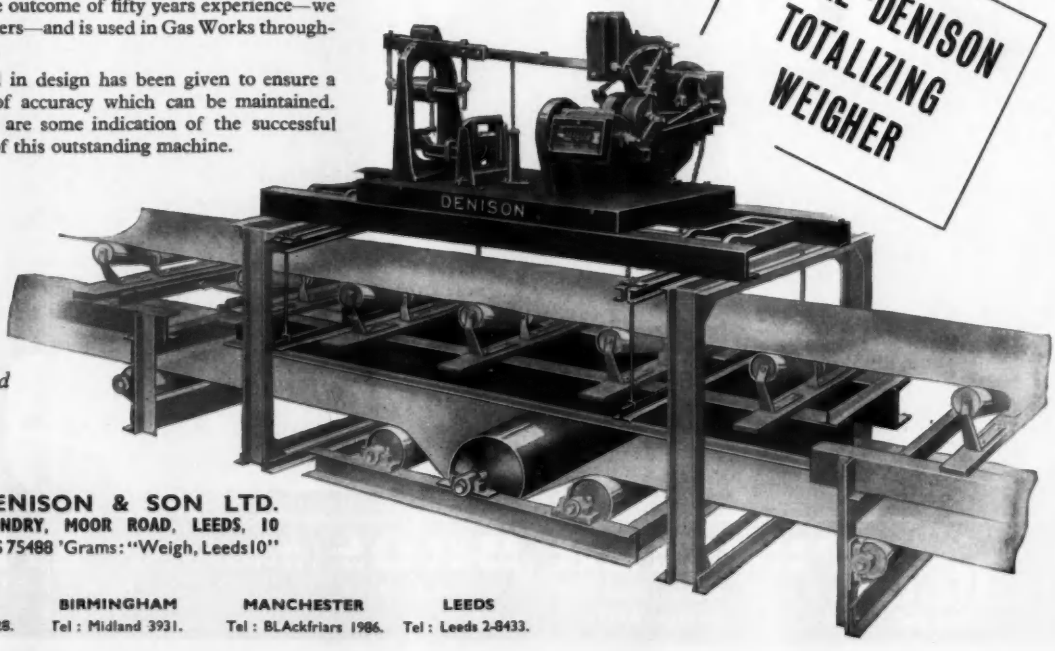

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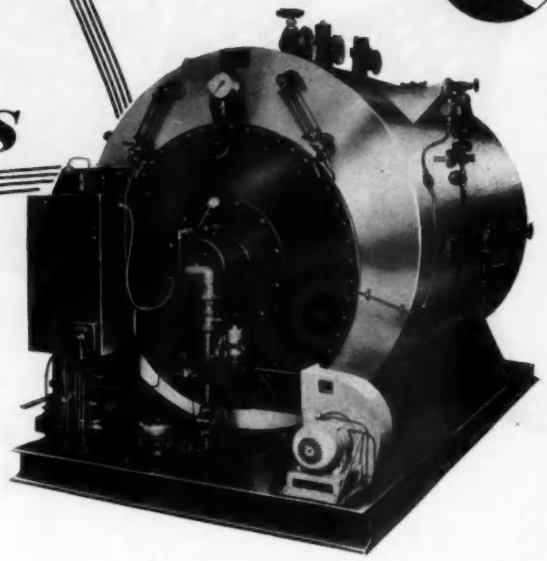

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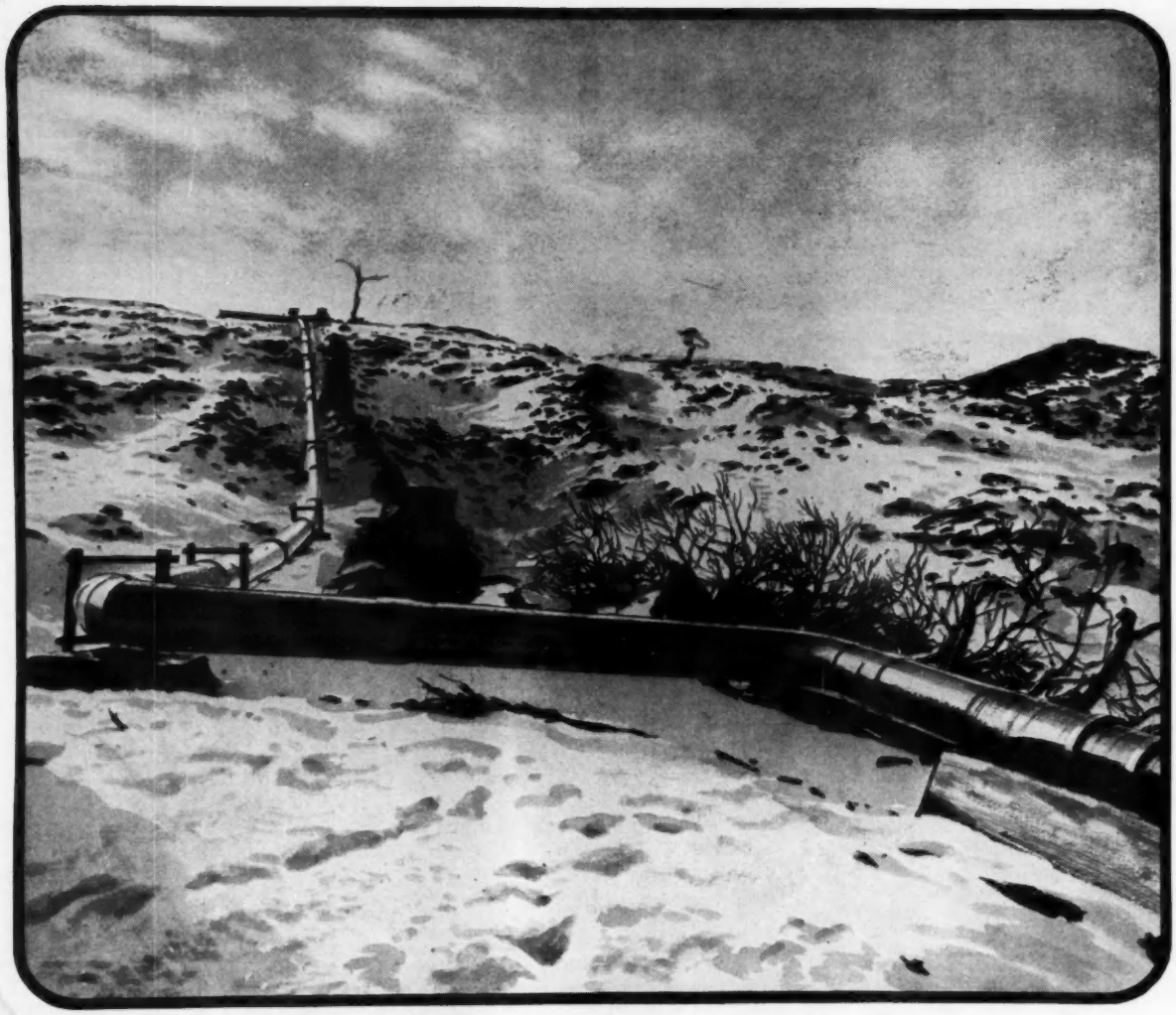

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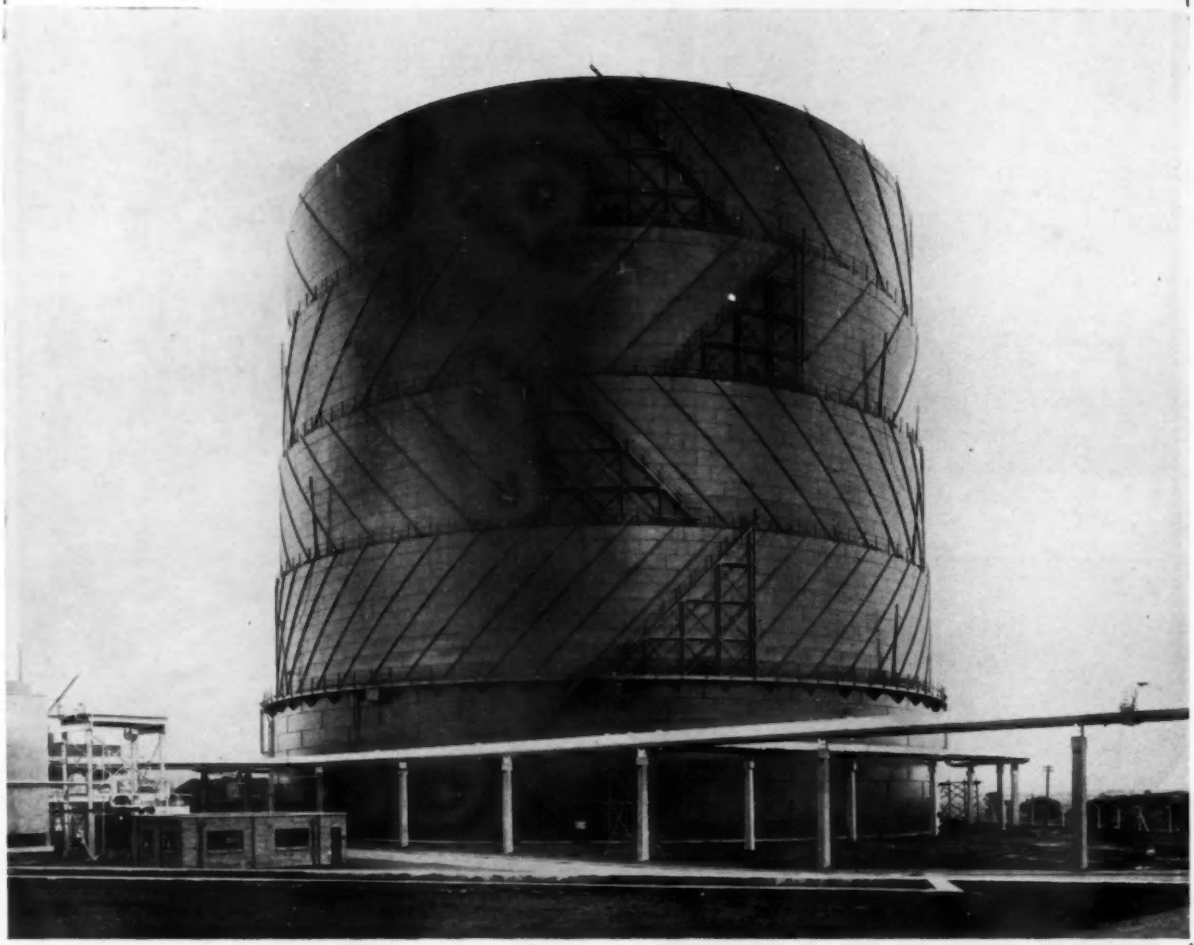

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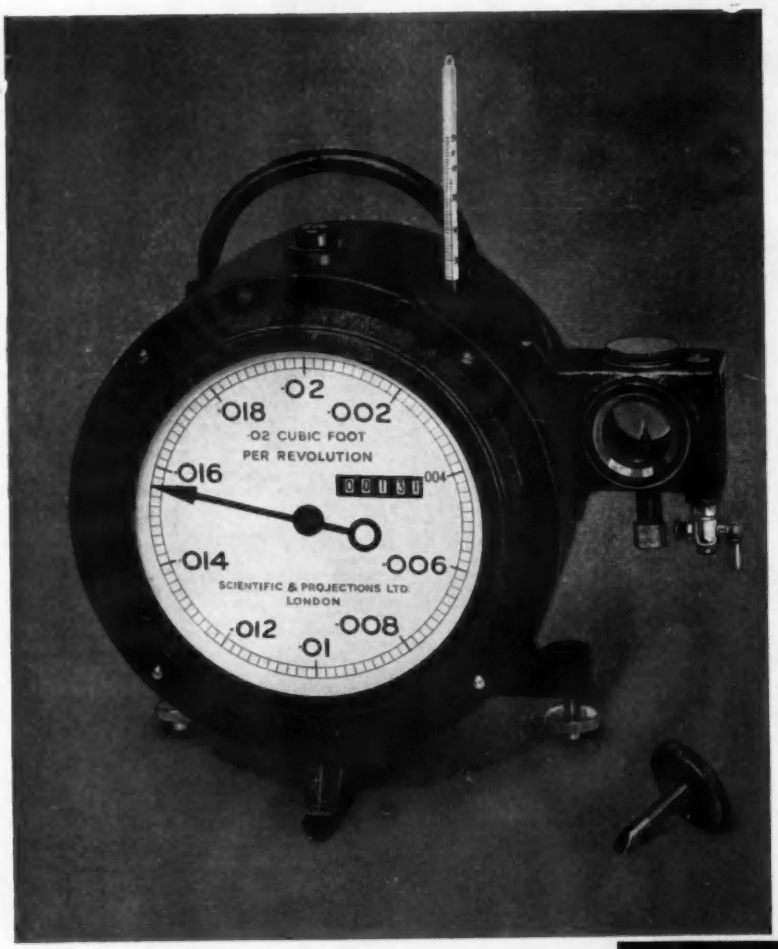

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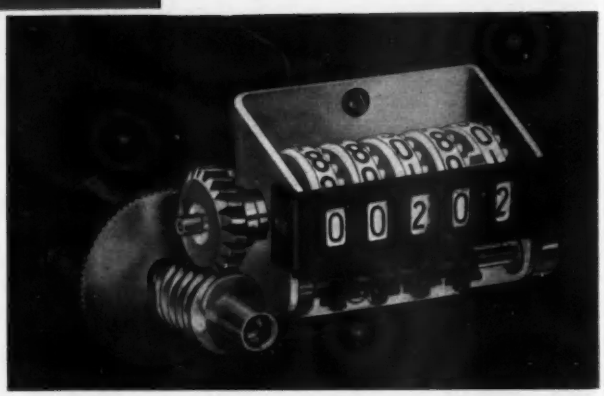

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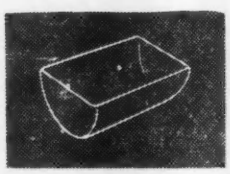
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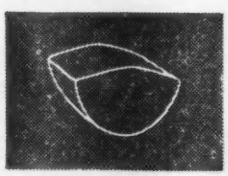
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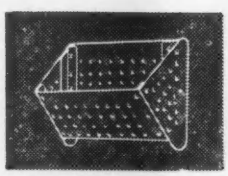
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Gas Journal

VOL. 291 NO. 4915 September 25, 1957

109TH YEAR

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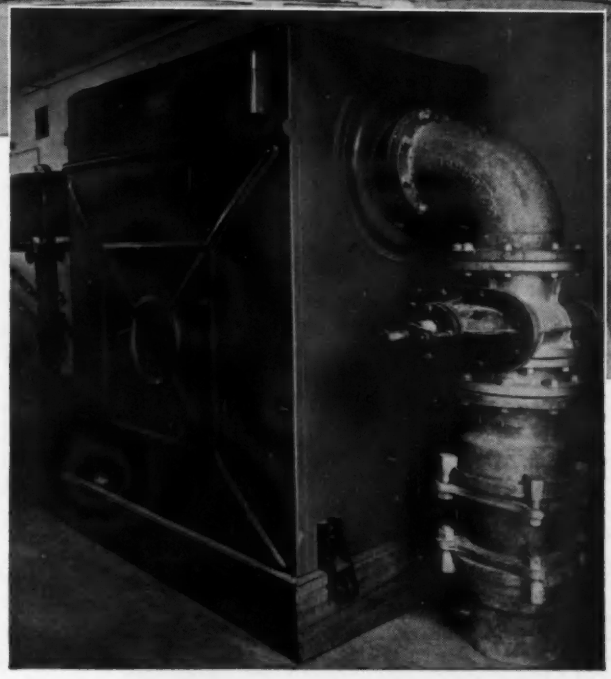

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Gas Journal

VOLUME 291. No. 4915. SEPTEMBER 25, 1957. 109th YEAR

The Design of Jet Burners

THE welfare of the gas industry appears to become more and more involved with the use of gas in industry. It is the large consumers of gas that justify the construction of large production units, in fact make them necessary, and although the load factor from this type of consumer is reasonably high during the week, during weekends and holiday times the demand will fall to almost zero. The gas industry continues to make headway in its supply of a fuel to the large-scale user of heat in industry, but it is of course the utilisation engineer and the designer of gas burners who are the points of contact between the producer and the user of the fuel. It therefore depends on the ingenuity of the designer and the theoretical and experimental knowledge of the engineer as to how successful the campaign to oust oil or electricity from industrial furnaces is going to be.

Today so many processes tend to be continuous in preference to the more conventional batch type of process. In the latter type the material to be heat treated was packed into the furnace and the temperature was brought up to the predetermined degree and held there until experience decided that the process was complete. Today with the demand for high productivity and the lowest possible labour force, the greatest output of the product with the lowest consumption of heat, and therefore fuel, is called for. The jet burner would seem to fulfil the demand for such a means of heating, for here the combustion of the fuel is so intense that a furnace in the conventional meaning of the word has become almost superfluous.

The object to be heat treated can be brought into the sphere of influence of the burner, held there until the correct temperature has been reached, and immediately quenched. Primary quenching may be adjusted in such a way that enough heat remains for a final tempering to the desired degree of hardness. This can be a continuous process and what perhaps is as important a point as any, each piece of the product has been treated individually. In the batch process there is always the danger of some parts of the batch becoming overheated, or another part undergoing insufficient heat treatment with only the majority being correctly treated.

The application of the jet burner to industrial heat treatment seems to be increasing and more and more applications are being found. In heavy industry where anything like mass production is not needed to the same extent, the chief advantage from this type of burner would seem to be its speed of heating and, by its great intensity, the concentration of heat on the spot where it is needed without damage to parts of the object which are not being processed. This would apply, for example, to light gauge welded pipework formed from sheet steel.

We feel that the idea behind the jet burner and its application to industry is so important that we are publishing two papers on the subject in this issue. One of these, ' Moulded Refractory Burners for Tunnels for Industrial Purposes,' was first read to the Midland Juniors as long ago as March, 1950, by W. M. Smirles and was first published by us at that time. The second is a paper, ' High Temperature Gaseous Jets as Applied to Some Manufacturing Processes ' by James B. Headwood, and was read at a joint conference on combustion held by the American Society of Mechanical Engineers and the Institution of Mechanical Engineers in London and Boston in 1955.

The later paper is of interest in showing the progress that had been made during the five years which separate the two papers. Interest in the subject was again brought to our notice by a Gas Council-sponsored demonstration given by the North Eastern Gas Board's Industrial Department at Leeds earlier this year and described in our columns at the time.

The American paper stresses the possible uses of the jet burner for mass production heat treatment methods, while the earlier paper makes more of the construction and description of the burner. This is only natural as then it may have been something of a novelty, and the complete extent of its application may not have been realised.

The demonstration which was arranged by the North

Eastern Gas Board showed that although the success of the application of this type of burner had been almost startling in every case, there were still difficulties to be got over. One of these is noise. At high gas rates the noise of the burner is almost deafening. This may be a matter of design and will eventually be overcome, but from many other points of view this type of burner really does seem to be a great step forward. The author of the American paper constantly refers to 'stoichiometric' mixtures of gases, and 'stoichiometric' quantities entering the burners. When such an exactly theoretical quantity of combustible material is taking part in the production of heat in a commercial type of burner, there cannot be any very great extravagance in fuel consumption.

Making a Stand

ALREADY it seems that the Chancellor of the Exchequer's show of willingness to make a real stand against inflation is putting a little more stiffness into the backbone of the pound; and already financial experts are beginning to forecast a mercifully short life for seven per cent. But, however soon the Bank Rate is clipped to a more reasonable percentage, it will not be before considerable effect has been made on publicly-owned industries. The Chancellor's intention in this direction is quite specific: He proposes to hold down 'the total of investment expenditure in the public sector, which was planned to rise substantially during the next two years, within the level attained this year.' This included, said the Chancellor in his statement, the sum of investment by Government departments, by local authorities, and by nationalised industries.

One can be misled by this, however. Because the gas industry spent £52 mill. on development projects in 1956, and £59 mill. has been approved for this work in 1957, it does *not* necessarily follow that a sum roughly between those two figures will be permitted to be spent in each of the two following years. What it seems to us will happen is that the *total* used by 'the public sector' of industry this year will guide the Chancellor as to the totals for 1958 and 1959. And fluent tongues will be required to prevent the dispensation of extra money to one piece of public ownership at the considerable expense of another. One of the Chancellor's objects, of course, is to encourage industry to see if it cannot achieve the same objects with less money; in this endeavour he will realise that when the gas industry says it needs money it really does need it—for cast-iron schemes that will ensure higher productivity—and that, in a time of reasonable financial stability, it would consistently be able to bring the price of gas down. The Coal Board and the Transport Commission, indeed, could take a few leaves from the gas industry's book since 1949 in handling the problems of productivity and modernisation with a minimum of unrest.

Assuming (and it is an hypothetical assumption) the success of these measures sufficient to allow the brake to be released soon, where could the damage caused by the enforced choking-off of money supplies be most lasting? Surely the school building programme generally, and technical school accommodation particularly, should be touched with the gentlest of hands. Just as it is essential to maintain the value of sterling by earning the money we spend, so is it vital that our turn-out of technicians is proportionately equal to that of our chief competitors. At the moment we are way behind—and no amount of 'hard work' and 'restraints' can adequately make up for lack of know-how.

Absenteeism in the Mines

NO aspect of industrial life today is more unsatisfactory than the frequency of strikes in the coal mines. They were described recently by Mr. J. D. M. Bell, of the Coal Board's industrial relations department, speaking at the Board's Summer School at Oxford. Of all the working days lost throughout industry as a result of strike action, 25% were through strikes in coal mining. The characteristic features of strikes in mining, said Mr. Bell, were that they were numerous, small and short. But, fortunately, in terms of working days lost, which was what mattered most in its effect on production, the relative position of the coal-mining industry was improving.

Mr. Bell remarked that given the choice between a lot of small irritating strikes and a relatively few really big ones, there could be no doubt the industry would much rather have the former. Part of the explanation of the high propensity to strike in the coal industry lay in the nature of the industry and of the community that surrounded it. This did not mean that anything approaching the present incidence of disputes had to be accepted as inevitable. The very fact that there was so wide a disparity between the incidence in different divisions showed that that was not the case.

These comments are interesting but disturbing in view of the quantities of coal lost. For example, in the first 36 weeks of the year 1,228,100 tons of coal were lost as a result of disputes, against 1,143,500 in the same period of last year. Yet there were 7,000 more workers on colliery books in the final week of August than a year ago.

What is the Coal Board doing about this problem which is cancelling out the benefits of mechanisation? According to the Chairman, Sir James Bowman, absenteeism is to be tackled by the Coal Industry National Consultative Council. The Council, comprising management and union representatives, is to send a letter to all divisional councils asking them to do all they can to reverse present absenteeism trends, pointing out that the reputation of the industry in the eyes of the public is at stake. This has a familiar ring about it; appeals to better nature have been tried in the past. We can only assume that the miners are now such privileged members of society that they are immune from any form of disciplinary action.

Coke Puff

ONE of the most conspicuous failures suffered by the gas industry is its inability to convert the public to the use of coke. Even today, generally speaking, people use coke only when they cannot obtain coal. The fact that the Clean Air Act is making a compulsory market for coke is fortunate indeed. Even so, coke is badly in need of some good public relations. It is because we regard this fuel as sadly under publicised that we paid particular attention to a leaflet describing 'Coke—the modern housewives' choice.' This is a simple throw-away affair produced by the West Midlands Gas Board, but it succeeds in presenting coke as it should be presented—as a refined, reliable, and inexpensive fuel. It explains why coke is as dear as coal, what size to use, what appliances are available to burn it in, and how to get the best results. Presented in a colourful and attractive layout this is a first-class piece of work. Other gas boards please copy.

Split Personality

THAT quiet gentleman of letters, Mr. Brian Hill, has written another book. So familiar is he becoming in the guise of author that it is only with a conscious effect that we can now visualise him in his more prosaic role of Publication's Officer to the Gas Council. Which occupation looms largest in his mind—the responsibility for producing a great number of high-quality brochures and pamphlets all dealing with gas, or the gentle and perceptive pursuit of a true translation of some French poet's verbal imagery? Does he, while struggling with the right interpretation of, say '. . . *et celui-là ta nuque rose, courte et grasse,*' have a sudden vision of how the section on large-scale dishwashing in a new leaflet might best be arranged; and does he find the answer, '. . . and one, I see, mimics your plump neck's rosy crease,' while prodding, metaphorically, a recalcitrant printer? Perhaps. Whatever the degree of overlapping may be, Mr. Hill manages to live both his lives very successfully, and since the results of his Gas Council work will be familiar to most of our readers, may we say that his new book *The Sky Above the Roof* is as sensitive as it is subtle. Whether this translation of 56 poems by Paul Verlaine will be a commercial success remains to be seen; of its success as a piece of artistic 'possession' there is unlikely to be any doubt. The book is published by Rupert Hart-Davis, price 12s. 6d.

Personal Notes

MR. A. J. PEECH has been appointed General Managing Director of the United Steel Companies, Ltd., in succession to the late Mr. Gerald Steel, who died on September 13. He was formerly Deputy General Managing Director. Mr. Peech, who is 52, joined the United Steel group in 1934 at the Workington Iron & Steel Company branch and subsequently became Assistant Commercial Manager. In 1937, he left Workington to become Secretary of Stanton Ironworks Co., Ltd., returning to United Steel as Sales Director in 1941. He was appointed Assistant Managing Director in 1944 and became Deputy General Managing Director in 1950. A member of the executive committee of the British Iron and Steel Federation, Mr. Peech is also a Director of the Federation's trading companies, British Iron & Steel Corporation, Ltd., and B. I. S. C. (Ore) Ltd.

MR. A. G. STEWART, Chairman and General Managing Director of Stewarts & Lloyds, Ltd., finds it necessary to resign from the Board of The Stanton Ironworks Co., Ltd., and will be succeeded as Chairman of The Stanton Ironworks Co., Ltd., by SIR FREDERICK SCOPES. Sir Frederick, who has been Managing Director of Stanton since 1942, retires from that office and will be succeeded by MR. N. C. MACDIARMID who is at present an Assistant Managing Director.

MR. J. B. TAYLOR has been appointed Safety and Training Engineer at the area H.Q. of the South Western Gas Board.

MR. REGINALD MAUDLING, who, as Paymaster-General, is spokesman in the House of Commons for the Minister of power, Lord Mills, and also the Prime Minister's special assistant and consultant on atomic energy matters, has been promoted to Cabinet rank.

MR. W. A. GREEN, of Paisley, was installed as President of the Scottish Western Junior Gas Association for the ensuing session at a recent meeting in Glasgow.

SIR WILLIAM C. FENTON, Managing Director of British Belting & Asbestos, Ltd., of Cleckheaton, and a leading industrialist in the West Riding, has just celebrated 50 years with the firm. To mark his jubilee the staff of the Cleckheaton concern and its subsidiaries are to present him with an oil painting of himself by the Leeds artist, Mr. Maurice de Suasmarez. He is also to receive an angler's cabinet of flies containing more than 200 specimens.

MR. C. C. PENFOLD wishes us to state that he, having relinquished his Directorships with William Sugg & Co., Ltd., and its Subsidiaries, is no longer associated with that Company.

MR. J. D. MELLOR is to retire from the Board of Directors of Plenty & Son, Ltd., on September 30, after 40 years' service. MR. S. R. F. DRAKE, who joined the firm in 1952, and who has been in charge of production for the past few years, has been appointed to the Board.

Diary

September 26. — NORTHERN JUNIORS: Newcastle-upon-Tyne. Film Show 'Pipe Line into Persia,' 2.30 p.m.

September 27.—LONDON AND COUNTIES COKE SALES CIRCLE: Visit to the Southern Gas Board's new Kingston works at East Cowes, Isle of Wight.

October 1.—SOUTH EASTERN G.C.C.: Caxton Hall, Westminster, London, S.W.1. 11 a.m.

October 2-4.—NATIONAL SMOKE ABATEMENT SOCIETY: Clean Air Conference, Hastings.

October 3.—NORTH OF ENGLAND SECTION I.G.E.: Some Engineering Problems in Connection with the Industrial Application of Nuclear Energy,' by Sir Claude D. Gibb. Paper delivered by Dr. A. T. Bowden, Newcastle, 2.30 p.m.

October 5.—EAST OF SCOTLAND JUNIOR GAS ASSOCIATION: Presidential Address of Mr. J. M. Brown. Social Club rooms, Albany Street, Edinburgh, 3 p.m.

October 7.—INSTITUTION OF CHEMICAL ENGINEERS: Papers on bursting discs by H. R. Wright, T. B. Philip, and J. W. F. Brown. Sir Hugh Beaver will take the chair.

October 11.—LONDON AND SOUTHERN JUNIORS: Prizegiving and Induction of new President, and Presidential Address.

October 16.—SOUTH WESTERN SECTION I.G.E.: A.G.M. and Chairman's Address.

October 21.—EASTERN G.C.C.: Connaught Rooms, Great Queen Street, Kingsway, London, W.C.2. 11 a.m.

'THE FUTURE OF NUCLEAR POWER'

The paper 'The Future of Nuclear Power,' by J. V. Dunworth, C.B.E., in last week's issue, will be presented to the Autumn Research Meeting of the Institution of Gas Engineers, and was published by kind permission of the President, Dr. J. Burns, G.M.

Safe Driving Awards

The Chief Constable of Newcastle, Mr. G. S. Jackson, presented safe driving awards to 112 drivers of the Tyneside Division of the Northern Gas Board at a special function held in Newcastle recently.

Mr. W. Sutcliffe, Divisional General Manager, disclosed that the Division's drivers covered 1,706,248 miles during 1956—an average of about 12,000 miles per vehicle—mostly in the congested streets of Tyneside, and that 92% of all the drivers had an accident-free year.

One driver was presented with a second bar to his five year medal; 73 drivers with five year medals, and 38 with diplomas.

B.C.R.A. DELEGATION TO AMERICA

Study of Coke Developments Since 1947

A DELEGATION of the British Coke Research Association left last Friday for the U.S.A., where a comprehensive tour of investigation will be made. The delegation is led by Mr. Leslie O'Connor, C.B.E., Chairman of the British Coke Research Association, Director and Deputy Chairman of the British Coking Industry Association, and Mr. G. W. Lee, Director of the British Coke Research Association.

The members are Mr. M. D. Edington, Durham Division Carbonisation Director of the N.C.B. and President of the Coke Oven Managers' Association; Mr. G. A. Hunter, Coke Oven Manager, Stewarts & Lloyds Ltd., Past-President of the Coke Oven Managers' Association; Mr. J. L. Lambert, Coke Oven Manager, Guest Keen Iron & Steel Co., Ltd., Past-President of the Coke Oven Managers' Association, and Mr. J. P. Graham, Headquarters Staff, British Coke Research Association.

The last visit to the United States by a delegation of experts of the coking industry in Great Britain was organised by the B.C.R.A. in 1947 and the present intention is to study the technical and economic developments of the American industry during the ensuing ten years.

Lines of Enquiry

Five main lines of enquiry have been decided upon as a basis for the tour:—

(a) Design in general of coke oven and ancillary plant, bearing in mind such points as productivity, manpower requirements, consistency of products and the avoidance of pollution.

(b) Correlation with the ironmaking process.

(c) General economic position of the coking and by-product industry.

(d) The main lines of research work and thought in America devolving from the treatment of coal and coke.

(e) The possibilities of the development of new methods of making coke and iron.

Programme

The detailed four weeks' programme includes visits to coke oven plants and iron and steel works as well as to research organisations and laboratories. The Koppers Co. Inc. and the Wilputte Coke Oven Division of the Allied Chemical & Dye Corporation have co-operated with the Association in planning the tour.

It includes visits to the Fairless works and the Pittsburgh laboratories of the United States Steel Corporation; Armco Steel Corporation, Middletown, Ohio; Interlake Iron Corporation, South Chicago; Inland Steel Company, Chicago; Youngstown Sheet & Tube Company, East Chicago; Armour Research Institute, Chicago; Mellon Institute, Pittsburgh; Eastern Gas & Fuel Associates, Boston; United States Bureau of Mines, Pittsburgh and Morgantown; Carnegie-Illinois Steel Corporation, Clairton; Tennessee Coal & Iron Corporation, Woodward Iron Corporation, Republic Steel Corporation, Birmingham, Alabama; Kaiser Steel Corporation, Fontana, California; Geneva Steel Compay, Salt Lake City, Utah; and the Colorado fuel and iron plant, Pueblo, Colorado.

On Friday of this week the delegation will hold a full day's joint meeting with the Coal and Coke Research Committee of the American Coke and Coal Chemicals Institute.

On October 9, at the conclusion of the tour, the members of the delegation will be received in Washington by the British Ambassador, Sir Harold Caccia.

To mark the promotion of Mr. S. Meunier to Northern Sales Manager, Radiation Group Sales Ltd., after 17 years as Area Manager in the north-west, group sales and service officers of the N.W.G.B. presented him with a salver which carried their facsimile signatures. The photograph shows the presentation being made by Mr. H. Butters, a member of the North Western Gas Board, with Mr. J. W. Rodgers, Sales and Service Officer, and Mr. F. A. Hooper, Radiation Ltd.

News From Ireland

Enniskillen Works Not to Close

STRABANE (Co. Tyrone) Urban Council at their meeting earlier this month received a letter from the proprietors of the Enniskillen (Co. Fermanagh) Gas Company emphatically denying a statement reported to have been made at a meeting of the Council to the effect that the Enniskillen gasworks was closing down.

The Company stated that they had no intention whatever of closing the works which were in a healthy and prosperous condition.

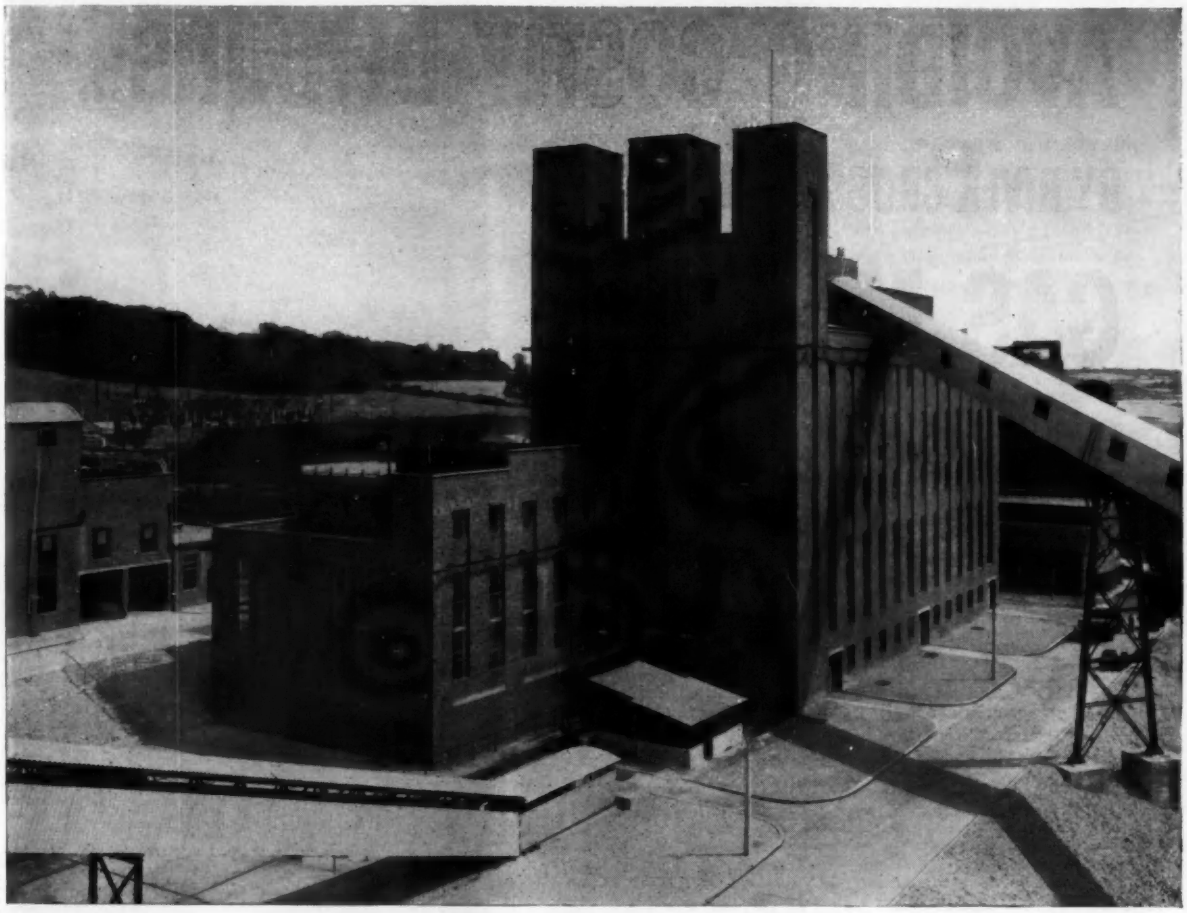
Ballymena (Co. Antrim) Borough Council has decided on the recommendation of the Gas Manager (Mr. C. W. Surman) to increase the price of gas to consumers by 10d. per 1,000 cu.ft., making the new price 9s. 2d. The Manager stated that since August, 1955, costs had risen by almost £7,500. There will be an increase of 8s. 4d. per ton in coke, making the price £7 3s. 4d. ex works.

When the members of **Newry** (Co. Down) Urban Council Gas Committee turned up for their monthly meeting they were prepared to recommend an increase in the price of gas, but they received a pleasant shock when they were informed that this would not be necessary.

'At Least Six Months'

Mr. M. Maguire (Secretary) informed them that as a result of increased efficiency at the works over the past few years they would be able to carry on for at least six months without having to consider an increase in the price of gas.

Mr. J. Collins (Gas Manager) pointed out that over 18 months there had only been an increase of 6d. He believed that with careful working he might be able to go another 18 months without a further increase.



The Intermittent Vertical Chamber house and waste heat boiler annexe at the New Kingston Works, Isle of Wight, of the Southern Gas Board.
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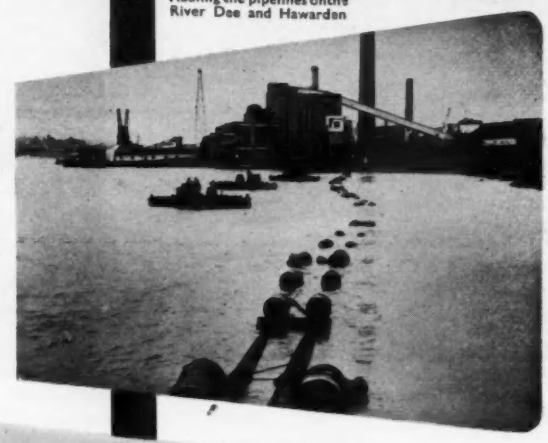

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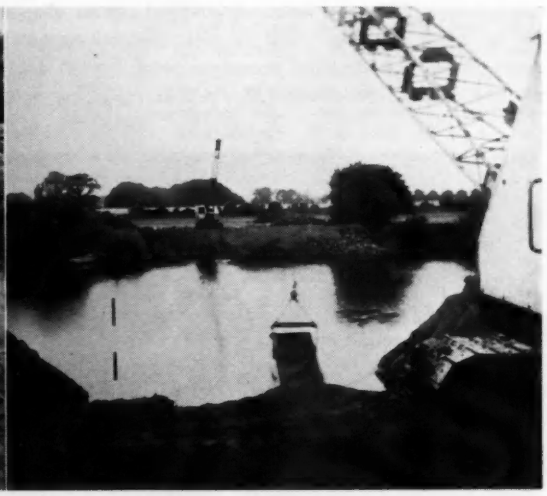
Pipeline Under the Ouse

BY virtue of their devotion to the laying of mains and services absolutely anywhere, distribution engineers in the gas industry must possess the ability to, as it were, infiltrate temporarily into other professions. They are required to know a great deal about the art of road making, something about agriculture, and a little about railway engineering. But it is when the progress of the main is halted by a river that they take on a new guise and acquire a hint of the mariner. River crossings are particularly interesting in that they demand less familiar and sometimes very unusual techniques. Seldom is it possible to use exactly the same technique twice.

Though not perhaps one of the most spectacular river crossings, that of the River Ouse at Fulford, Yorkshire, had some quite novel features. The crossing became necessary during the laying of a 16 in. main from Leeds to York, to extend the West Yorkshire grid. Three mains were laid—the high pressure grid main; the York Undertaking district main; and the standby for either of the others. The job facing the North Eastern Gas Board was the construction, assembling and laying of these three mains across this 150 ft. wide navigable river—without stopping traffic during operations. Apart from the Board three local authorities were interested in the operation—the Yorkshire Ouse River Board, the York City Engineer, and the Ouse Navigation Authority. The work was entrusted to Land & Marine Contractors, Ltd., of Bromborough, Cheshire.

The necessary excavation was carried out by a dragline on each bank and a floating grab in the middle of the river. The grab deposited into barges which were emptied down stream. By this means a trench 5 ft. 6 in. in depth was produced on the bed of this 20 ft. deep river.

Dredging the river bed. The floating grab can be seen operating in mid-stream.



The dragline on each bank.

Wrapping in progress.

The first pipe assembled.

The three pipes ready for launching.

The assembly site for collecting and fabricating the main was 300 yards upstream and here the pipes of $\frac{3}{8}$ in. steel were cleaned and double wrapped with a sheathing of 'thermo-glass' fibre to within 1 ft. of their ends. They were then assembled and welded, the welds being tested by gamma-ray radiography. The joints were then wrapped and the wrapping on the whole pipe was tested for soundness by the holiday detection unit. Both these operations were carried out by Metal & Pipeline Endurance, Ltd. A 2 in. square mesh steel fabric was then fixed round the pipe and finally a 1 in. coat of concrete was applied by the Gunite process to provide negative buoyancy.

Each pipe was then launched and floated down river under three pontoons to the approximate position. Draglines on each bank at the crossing point manœuvred the pipe into the final position. The pipe was then released from the pontoons and allowed to sink into the trench. Finally, the pipes were covered with cement and the trench backfilled with cliffstone.

Guniting in progress.

The launching in progress.

Landing. The pipe is still supported by pontoons and attached to the dragline.

All three pipes in position and undergoing test.

In Brief

CONFERENCE WILL EXAMINE NIFES REPORT

A CONFERENCE 'to bring together all interested parties, particularly users and distributors of fuel, and combustion appliance makers, in order to examine the third progress survey of the National Fuel Efficiency Service, is to be held at Harrogate on November 5 and 6.

Details and application forms can be obtained from the Combustion Engineering Association, 6, Duke Street, St. James's, London, S.W.1, who are holding the conference.

Colonial Gas Holdings, in association with Australian Gas Light Company of Sydney, has formed a new company to distribute liquid petroleum gas for use as fuel and power. The company, known as Thermal Traders Proprietary, has been registered in Canberra with a nominal capital of £A5 mill. The liquid petroleum gas will be supplied by Shell Oil Company's refinery at Geelong, Victoria.

The Purchasing Officers' Association has just published a supplement to its list of members issued in May, 1956. Copies, price 5s., may be obtained from the Association at Wardrobe Court, 146a, Queen Victoria Street, London, E.C.4. A small number of the original lists are still available at 10s. 6d. each, or 15s. for the list and supplement combined.

A course on industrial and factory law will be held under the auspices of the Industrial Welfare Society on October 22-24 at Robert Hyde House, 48, Bryanston Square, London, W.1. Particulars can be obtained from the Secretary at that address.

BTR Industries Ltd. (formerly British Tyre & Rubber Co., Ltd.) has opened a new branch office and warehouse at Marshall House, Marshall Street, Birmingham, 1 (Tel: Midland 4602). The new office will be managed by Mr. D. H. Turner. Comprehensive stocks of BTR industrial rubber products and automobile accessories will be carried.

The Houldsworth School of Applied Science, Leeds University, is this year holding special courses on petroleum technology, gasification practice, by-product coking processes, coal gas manufacture, and disposal of gasworks and coke ovens waste liquors.

The Chief Constable of Renfrew and Bute has asked the Scottish Gas Board to install credit meters in private houses rather than the prepayment type. He said: 'Last year there were 118 cases in the area of prepayment gas and electricity meters being forced open.'

STILL BENT ON IMPROVING SERVICES, THE

Sc.G.B. Approves Projects Totalling Nearly £2 Mill.

THE Scottish Gas Board is preparing to spend the best part of £2 mill. on improving its services. Four-figure projects approved by the Board, and reported to a meeting of the Scottish Gas Consultative Council in Edinburgh on September 13, amount to £1,914,918. Over half of the total will be spent in the Glasgow district.

The district figures show the following break-down: Glasgow, £1,204,041; Central, £361,600; Edinburgh, £324,020; South-West, £24,208; and North, £1,049.

The high Glasgow figure is chiefly accounted for by arrangements for the handling of coke oven gas. A sum of £728,000 is earmarked for a project to install purification and compressing plant at Coatbridge gasworks to handle coke oven gas which is to be received from the Gartsherrie coke ovens of Baird's & Scottish Steel Ltd. The purified gas, after compression, will be transmitted into the Glasgow gas grid to supply Glasgow and other undertakings. In connection with this scheme a further £131,000 is allocated for the provision of an 18-in. diameter spun iron main from Hollandshurst to Provan gasworks, Glasgow.

Over Half For Glasgow District

Another part of the scheme deals with the transmission of crude coke oven gas from the Dumbreck coke ovens of the N.C.B. to Kilsyth and transmission of purified coke oven gas from Kilsyth to Kirkintilloch. The cost of laying an 8-in. diameter spun iron main from Dumbreck to Kilsyth and from Kilsyth to Kirkintilloch, together with purifiers and ancillary equipment at Kilsyth, will be £86,000. A further sum of £43,000 will be needed for the laying of a 10-in. diameter spun iron main from Twechar to Mollinsburn.

New Compressor House

The third section of the Glasgow scheme deals with a project to allow substantial supplies of crude coke oven gas to be transmitted from the new Ravenscraig coke ovens of Colville Ltd., to the Uddingston works, where purification will take place. The purified coke oven gas will then be used to supply the Lanark gas grid. A sum of £178,000 is being set aside for the provision of an 18-in. diameter spun iron main from Ravenscraig to Uddingston, and the construction of a new compressor house at Uddingston works. There is a further project to lay a spun iron main of 6-in. diameter from Cardown Colliery to Provan gasworks for the purpose of transmitting limited volumes of methane. The laying of the main and the installation of a governor and meter will cost £26,000.

Gas Grid

The expenditure of £361,600 in the Central District is concerned with the project to construct a gas grid to supply Montrose, Brechin, and Carnoustie with gas, thereby enabling production to cease at these works.

The main item in the Edinburgh district expenditure is £293,000 for the installation of new tower purifiers at Granton gasworks.

Emett—and his 'special'

IT MUST HAVE PUNCH, HE SAID

MR. ROWLAND EMETT, the *Punch* cartoonist and creator of some weird railways and railwaymen, recently ordered a gas fire from the South Eastern Gas Board for his home at Ditchling, Sussex. But, being Emett, he wanted a very special gas fire for a very special old wrought-iron fireplace.

The Board found just what was required—a six radiant Metro inset fire, with side dogs, modified to fit the fireplace.

Mr. Emett is delighted with his new acquisition which pleases his artistic sense as well as warming up the room much more quickly than was previously possible.

From a paper to the Joint Conference on Combustion, held by the American Society of Mechanical Engineers and the Institution of Mechanical Engineers, in London and Boston during 1955.

High Temperature Gaseous Jets as Applied to Some Manufacturing Processes

By JAMES B. HENWOOD, B.S., Mem.A.S.M.E.,

SELAS CORPORATION OF AMERICA, PENNSYLVANIA.

WITH few exceptions, manufactured products or the materials comprising them require that physical or chemical changes be permitted to take place—under the influence of heat—during their preparation for the consumer market. The time rate of addition or removal of heat in these materials not only often determines whether a product can be produced, economically, or whether its quality is superior to others; but, in some cases, even determines whether or not it can be manufactured. The paper attempts to demonstrate current practices and trends embodying the application of high-temperature jets to manufacturing processes.

Thermal jets have long been associated with the transfer of heat to process materials. High-velocity, high-temperature jets are readily produced by combustion of industrially available fuel gases with air and/or oxygen and represent the source of thermal jets discussed in this paper. This does not imply that other energy sources cannot be utilised to achieve similar effects. While considerable information has appeared in the literature pertaining to applications of thermal jet systems to transportation propulsion, relatively little information has appeared on the subject of the application of high-velocity jets to industrial processing.

In these two fields of application the jet possesses common features (Smith 1944)*, namely, means for compressing oxidant and fuel, for adding heat to the mixture by combustion, and for utilising the combustion products. In aircraft propulsion the objective is to produce the greatest possible thrust per lb. of engine and per lb. of fuel consumed. In industrial heating processes the objectives are thrust, heat transfer, chemical reactions and controlled utilisation of these effects to produce new or improved products more economically and efficiently.

During the past decade the science of flames, combustion, and heat transfer has received unprecedented attention owing partially to emphasis on major improvements in transportation propulsion methods. It is of interest to those devoted to other fields of endeavour to be informed of recent progress of contemporary jet applications in the manufacturing industries.

Industrial Applications

Jets resulting from gaseous combustion possess numerous properties of economic importance to the process industries. Before they can be adequately utilised, their mode of creation, disposition, and implications in relation to specific processes, must be evaluated.

The conversion of chemical potential energy into heat and mechanical energy occur during combustion, accompanied by great rise in temperature and the appearance of sensible heat in the products of combustion. It is with these gases that time-temperature cycles must be satisfied. Consequently, their proper disposition with respect to an existing or contemplated process is a problem of major importance and one that deserves the greatest attention toward the successful solution of processing problems.

To utilise fully the benefits produced by combustion of oxidant and fuel-gas mixtures, the following objectives should be recognised:

(1) The combustion reaction should take place in the minimum possible time to confine it to the minimum space required, in order to utilise the highest possible energy level;

(2) the high-temperature gases thus formed must transfer heat, either directly or semi-directly to the object, in a controlled manner, as dictated by the requirement of the process in order that time-temperature requirements can be met;

(3) the velocity and temperature of the jet must be developed to solve process problems involving simultaneous heating, mechanical forming, and conveying of materials.

The Purpose of a Burner

Combustion of fuel-gas necessarily implies the use of a burner which is more technically a transducer. A burner is generally considered to be a device (Am. Gas Association 1951) for the release of oxidant and combustible into the combustion zone. A transducer, by definition (Webster, 1947) is a device that receives energy in one form and delivers it in another, suggesting by its more specific meaning that planned conversion and distribution of energy is incorporated in its design and application. Nomenclature is relatively unimportant except for the purpose of mutual understanding; consequently the word burner will continue to be used throughout the paper with emphasis on the definition of transducer.

An internal-combustion nozzle designed for high-velocity jet applications is composed fundamentally of the parts illustrated in Fig. 1, and functions in the following manner: Compressed

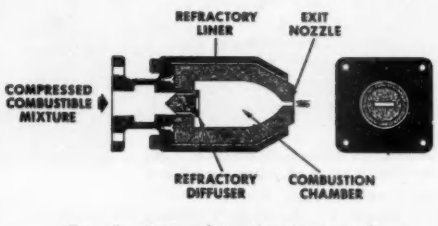


Fig. 1. Internal-combustion nozzle.

stoichiometric combustible mixture (either premixed or nozzle mixed) is admitted through diffuser into the combustion chamber, wherein combustion is completed—at high to very high rates per unit of combustion volume—dependent upon considerations of design and required performance. The refractory liner reduces heat loss and, when incandescent, contributes to the attainment of high combustion rates.

Completely burnt combustion products issue from the exit nozzle at approximately 3,000°F. (Selas Corp. a) (for stoichiometric mixtures of air and commercial fuel-gas) at velocities dependent upon the physical properties of the combustion products and the nozzle pressure ratio.

Fig. 2 illustrates a nomogram for calculating theoretical jet velocities of gases expressed as a function of nozzle pressure ratio, ratio of specific heats, specific heat, and the temperature of the gas entering the nozzle. The included data, for purposes of illustration, indicate typical practical values of gas temperature at inlet to the nozzle, corresponding average specific heat, and the ratio of specific heats for the temperature ranges

* An alphabetical list of references is given in an Appendix.

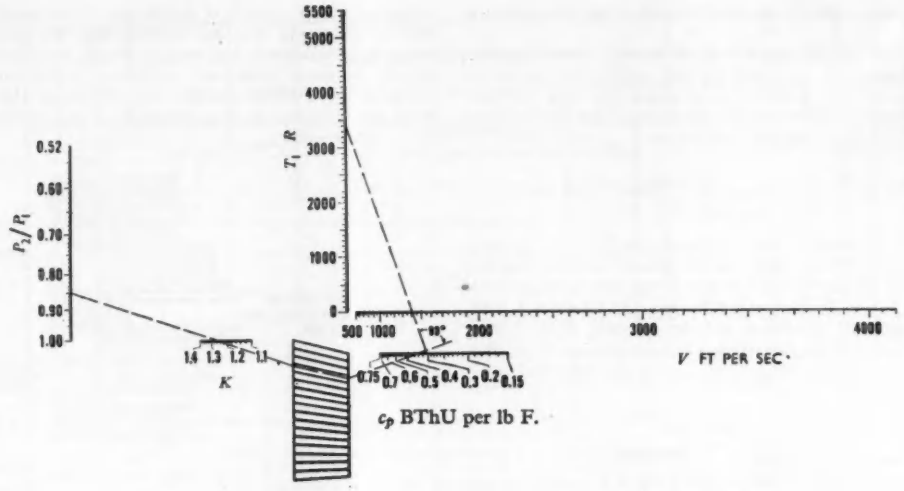


Fig. 2. Nomogram for calculating theoretical jet velocities.

Air-fuel gas mixture (stoichiometric)	Gas temperature at inlet to nozzle, R	Average cp B.Th.U. per lb. F	Average K
Methane and air (21 per cent. oxygen, 79 per cent. nitrogen)	2,900–3,400	0·350	1·260
Methane and oxygen-enriched air (42 per cent. oxygen, 58 per cent. nitrogen)	3,900–4,400	0·405	1·220
Methane and pure oxygen (100 per cent. oxygen)	4,900–5,400	0·517	1·166

$$V = \left[2gJc_p T_1 \left\{1-(P_2/P_1)^{(K-1)/K}\right\}\right]^{\frac{1}{2}}.$$

- V Velocity of gas at exit of nozzle, ft. per second.
- T_1 Temperature of gas entering the nozzle, R.
- P_1 Upstream chamber pressure, lb. per sq. in. abs.
- P_2 Exit pressure, lb. per sq. in. abs.
- c_p Specific heat of gases at constant pressure, B.Th.U.-per lb. per deg. F.
- g Conversion factor in Newton's law of motion = 32.2 ft. × lb. mass/sec.^{2} × lb. force.
- J Mechanical equivalent of heat 778 ft. lb. per B.Th.U.
- K Ratio of specific heats c_p/c_v.

suggested; when burning stoichiometric mixtures of methane and air, methane and air enriched with oxygen, and methane and pure oxygen. The gas temperature range at the inlet to the nozzle is typical of existing designs where the internal area of the refractory combustion chamber approaches a minimum per unit volume, and the heat release is greater than 10 mill. B.Th.U. per cu.ft. of combustion vol. per hour.

The nomogram example illustrates a solution of the equation for a desired nozzle-exit velocity of 1,400 ft. per second*; given an inlet-nozzle gas temperature of 3,400°R, an average specific heat at constant pressure of 0.35 B.Th.U. per lb. deg. F., and an average ratio of specific heats, K, of 1.26, for which the required nozzle pressure ratio is 0.85. Therefore, when the nozzle is discharging to the atmosphere, a combustion-chamber pressure of 2.6 lb. per sq. in. gauge is required to produce the desired velocity. What does this mean in terms of convection heat transfer?

Fig. 3 illustrates the effect of gas velocity on the convection heat-transfer coefficient h_c expressed in B.Th.U. per hour per sq. ft. per deg. F. for various diameter cylinders for the special case of full flow at right angles across the outside of a cylinder (McAdams 1942). The gas (air) temperature is 3,000°F., indicative of the temperature at the exit of the internal-combustion nozzle previously described when burning fuel-gas with air. The physical properties of air are sufficiently close to theoretical combustion products to permit their use for purposes of illustration. In Fig. 3, the convection heat- transfer coefficient h_c for a cylinder of diameter 0.25 in. is equal to approximately 188 B.Th.U. per hour per sq. ft. per deg. F. at

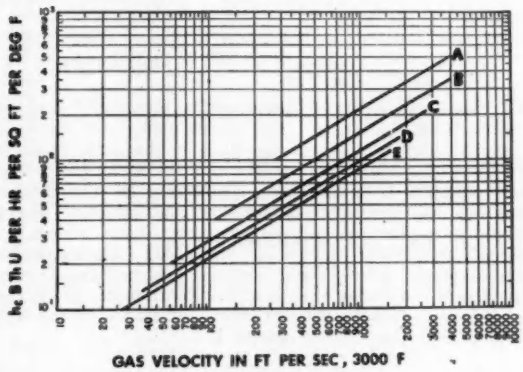


Fig. 3. Coefficient of heat transfer by convection with an air stream flowing at right-angles across the outside of a cylinder.

Air temperature 3,000°F.

R $D_o V/\nu_f = 1{,}000-50{,}000$

D_o Outside diameter of cylinder, inches.

A D_o=0·10. B D_o=0.25. C D_o=0.50.
D D_o=0.75. E D_o=1·00.

* The temperature of the gases at 1,400 ft. per second is slightly less (approximately 75°F.) than at the inlet to the nozzle, owing to the increase in kinetic energy of the jet. This effect is neglected in this paper.

a gas velocity of 1,400 ft. per second and a gas temperature of 3,000°F.

Illustrating the relative magnitude of heating rates possible using high-velocity jets, by applying the information given in Figs. 1, 2, and 3, it is possible to estimate the time to heat an object through a given desired increase in temperature by applying the following integrated equation:

$$\theta_c = 3{,}600 \times \frac{W}{A} \times \frac{c_p}{h_c} \times \log_e \frac{t_j - t_1}{t_j - t_2} \text{ (Selas Corp. b, 6)}$$

where θ_c is the heating time from temperature t_1 to t_2 by convection in seconds; W the weight of the object heated, pounds; A the cylindrical area of the object heated, sq. ft.; c_p the specific heat of the object, B.Th.U. per lb., F. (average between t_1 and t_2); h_c the convection coefficient of heat transfer, B.Th.U. per hour per sq. ft. per F.; t_j the temperature of the jet, F.; t_1 the initial temperature of the object, F.; and t_2 the final temperature of the object, F.

The following conditions are proposed:

(1) Temperature of jet constant at 3,000°F.
(2) Initial temperature of the object t_1, 100°F.
(3) Final temperature of object t_2, 1,500°F.
(4) Dimensions of object, ¼ in. diameter by ½ in. long.
(5) Material of object, low carbon steel (490 lb. per cu.ft.).
(6) Average specific heat of object between the temperatures t_1 and t_2, 0.15 B.Th.U. per lb. F.
(7) Convection coefficient, 188 B.Th.U. per hour per sq. ft. per F.
(8) Convection coefficient, constant during heating of object.
(9) Heat conduction in object, neglected.
(10) Radiation from object during heating, neglected.
(11) Phase change in object during heating, none.

Under these conditions the heating time becomes

$\theta_c = 5$ seconds (3,000°F. jet, velocity 1,400 ft. per second).

If the velocity be reduced to 150 ft. per second the heating time becomes

$\theta_c = 19$ seconds (3,000°F. jet, velocity 150 ft. per second).

In addition to the relatively high convection heat-transfer coefficients available with jet-type burners, the high-velocity jet produces shear and drag upon objects so heated. This combination effect permits new processes and products, several of which include:

(1) Continuous forming of micro-fine filaments from viscous materials;
(2) atomisation of molten liquids;
(3) combined continuous melting and atomisation of liquids at the jet;
(4) localised heating of metals preparatory to effecting metallurgical transformations in prescribed patterns;
(5) simultaneous fluidising, heat treatment, and conveying of granular materials;
(6) submerged direct heating of liquids;
(7) continuous singeing of textiles at high speeds;
(8) fire polishing of glass.

Of equal importance to heat transfer, shear, and drag, but of distinct significance, are the present studies of ultra-high-speed chemical reactions taking place in the flame fronts of high-temperature gaseous jets (Lessing 1953). 'These high-speed reactions have increasing significance in rocketry, biochemistry, upper-atmosphere researches, air pollution and an entirely new class of chemical processes from which may develop completely automatic, high-speed, continuous-flow chemical plants.' The engineer's contribution to these developments lies in translating basic scientific research into production applications; and represents an important branch of the technology of high-temperature gaseous jets.

The Radiant Burner

A second type of burner utilises high-velocity high-temperature gaseous jets in a different manner to achieve an entirely different heat-transfer effect on process materials.

A radiant type of burner is illustrated in Fig. 4 and functions as follows: Stoichiometric combustible mixture, either pre-mixed or nozzle mixed, is discharged from the diffuser, in the form of numerous jets, into contact with the surface of a relatively flat refractory concavity. Fluid flow and rapid heat-transfer between gases and refractory is the basis for design of concavity. Within normal capacity range the gases escape from the concavity as final products of combustion.

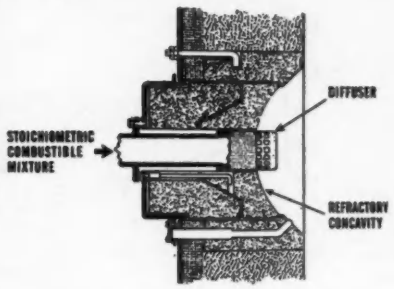


Fig. 4. Radiant burner.

Certain inherent features of the radiant burner permit processing methods and resulting products to be re-evaluated on bases other than cost of fuel or reduction of heating time alone.

These features include:

(1) Rapid conversion of chemical energy in the fuel into sensible heat in the gases within the geometric confines of the cup. This is accomplished by utilising the effect of turbulence and the reaction supporting properties of incandescent refractory;

(2) partial conversion of sensible heat in the gases to high-level radiant energy in the refractory concavity. This effect is obtained by designing to permit control of convection heat-transfer coefficients (gases to refractory) to the surface of the refractory concavity;

(3) discharge of high-temperature combustion products into the work space—but not at the work itself—thereby minimising localised impingement upon the process material.

Practical Significance

The practical significance of the radiant burner to the process engineer may be understood as follows:

(1) Heating chamber dimensions are a function of product dimension and the radiation configuration factor between emitter and receiver—whichever is of controlling importance in the contemplated design;

(2) the radiant burner permits new methods of handling process-products, involving small, rugged heating structures (semi-furnaces) of low heat-storage capacity and nearly instantaneous radiant temperature response to production demands;

(3) process materials can be exposed to time-temperature cycles on an individual, continuous basis, thereby greatly minimising the possibility of non-uniform treatment as contrasted with bulk, long-cycle heating on a furnace hearth;

(4) exposure time of product to temperature is drastically reduced (from hours to minutes or seconds) often creating improved physical properties in the product;

(5) application of a number of burners to a heating unit, thereby utilising thermal energy more effectively while at high energy levels. High rates of heat transfer to the object are achieved with geometric control of heat-transfer pattern;

(6) radiant burners are placed close to the object without the danger of localised heating, owing to the absence of 'torching,' by high-temperature gases, upon critical material.

Refractory enclosures operating at average wall temperatures above 1,750°F. transfer, by wall radiation, 80% of the heat absorbed by the object (Genna and others 1954). Fig. 5 illustrates the distribution of the various modes of heat transfer. An increase in percentage of total heat-transfer by convection is evident as the average sample temperature approaches the furnace wall temperature and the radiation term approaches zero.

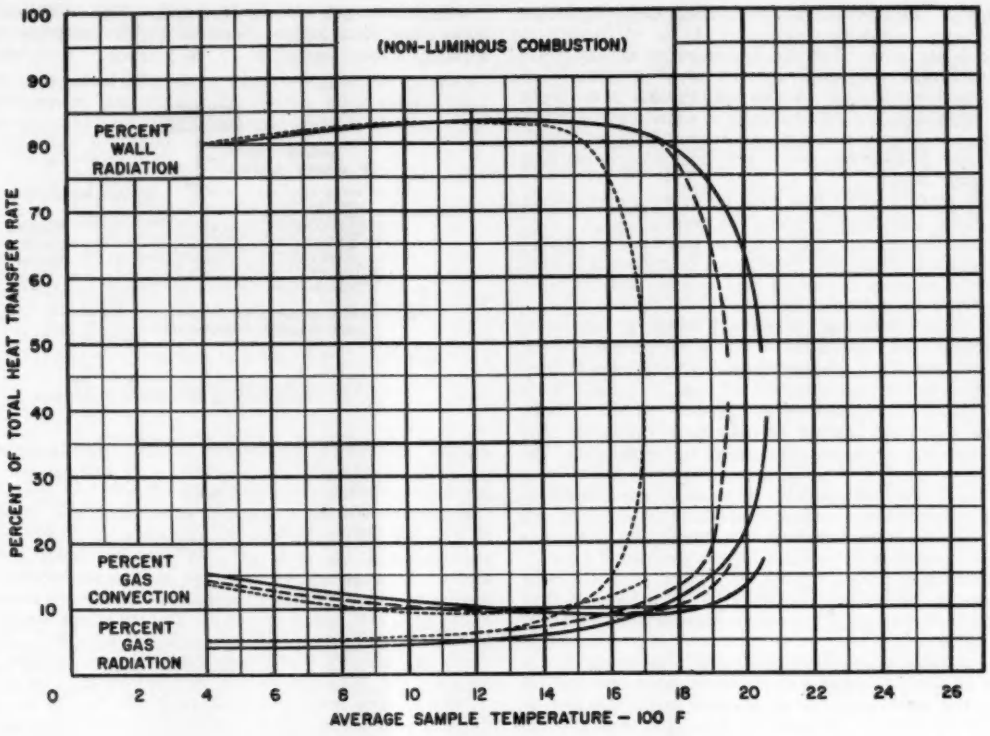


Fig. 5. Curves for heat-transfer rates in a gas-fired furnace. 80% of its heat is transferred by radiation from the furnace walls.

- - - - - - - - Average furnace gas temperature 1,960°F.
Average furnace wall temperature 1,750°F.
— — — — Average furnace gas temperature 2,250°F.
Average furnace wall temperature 2,010°F.
——— Average furnace gas temperature 2,400°F.
Average furnace wall temperature 2,100°F.

It should be noted, however, that the high percentage of heat transferred by radiation is maintained for a higher sample temperature if the wall temperature is increased. The radiant burner is one method of approaching this condition by the introduction of many radiant sources (burners) into the refractory wall, thereby converting part of the highest-temperature sensible heat in the gases to radiant energy at high temperature. The transfer of heat by radiation to workpiece areas is by nature a simpler process to evaluate and control than that by high-temperature *random* convection.

Fig. 6 (McAdams, 1942) illustrates the coefficient of heat transfer by radiation when the two surface temperatures are known. The coefficients have been extended to include surface temperatures up to 5,000°F. and are therefore convenient for estimating the heat transferred by radiation for temperature

TABLE 1. HEATING TIME FOR METALS BY RADIATION HEAT TRANSFER

Material	Size	Temperature of enclosure, °F.	Initial temperature of object, °F.	Final temperature of object, °F.	Heating time
Carbon steel, round	Diameter 2 in.	2,300	60	2,000	6·6 minutes
Carbon steel, round	Diameter 2 in.	2,700	60	2,000	3·0 minutes
Bright steel strip ..	0·010 in.	2,000	60	1,300	5·2 seconds
Bright steel strip ..	0·010 in.	2,500	60	1,300	2·3 seconds
85–15 brass strip ..	0·010 in.	2,500	60	1,300	1·7 seconds

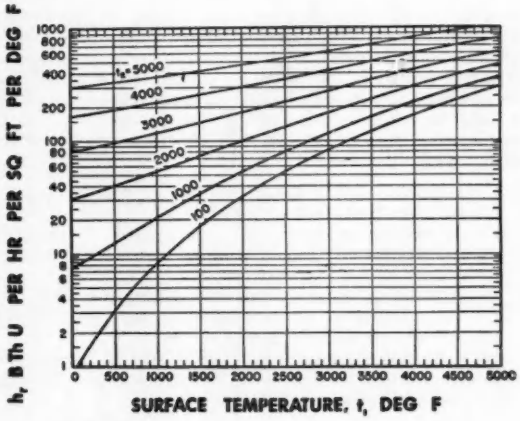


Fig. 6. Coefficient of heat transfer by radiation.

t_2 Temperature of surface 2.

$$h_r = \frac{q_r}{A_1(t_1 - t_2)} = \frac{0{\cdot}171 c_1 \left[\left(\frac{T_1}{100}\right)^4 - \left(\frac{T_2}{100}\right)^4\right]}{T_1 - T_2}$$

h_r B.Th.U. per hour per sq. ft. per deg. F.
q_r B.Th.U. per hour.
A_1 Area, sq. ft., surface 1.
ϵ_1 Emissivity of surface 1 = 1.0.
T Absolute temperature, deg. R.

differences occurring when oxygen enrichment or preheated air are used.

In Table 1 are given theoretically computed values (Selas Corp. c) which represent heating rates obtained in actual practice. In these calculations certain assumptions have been made: (1) transformation phase change in metals is neglected; (2) heat transfer by conduction in the metal is neglected; and (3) the area of the enclosure is large compared to the area of the enclosed object.

It is evident from Table 1 that small increases in temperature of the enclosure significantly reduce the heating time.

The effectiveness of radiant heating can be efficiently utilised only when the conversion (by convection) of the sensible heat in the combustion gases to radiant heat in solid surfaces takes place under controlled conditions.

Industrial heat processing applications utilising techniques herein described often require that the final temperature of the object be controlled by a predetermined exposure time to continuously reproducible heat-transfer conditions. This method is successfully practised by industry, and exposure-time tolerances of less than $\frac{1}{10}$ second are not uncommon. This means that heat release with respect to time must be under accurate control.

Numerous devices, designed to eliminate these factors as uncontrolled variables, are well developed, and practically any magnitude of heat-processing load can readily be accommodated by instruments and machines for the purpose of (1) supplying constant ratio air-gas pre-mixtures under pressure up to 15 lb. per sq. in. gauge, and (2) supplying air and gas of constant ratio piped separately to process burners up to 500 lb. per sq. in. gauge.

The proper selection of air/gas proportioning equipment is determined by the mode and rate of heat transfer required by the process, the mechanical energy required in the jet, and by economic considerations. Equipment is readily available for the purpose of supplying burners with air and fuel-gas at constant ratio, over wide ranges of pressure and flow rates, and within tolerances dependent upon the requirement and economics of the process.

Typical Applications and Installations

A technology is able to survive and grow only when the concepts upon which it is based remain economically valid. An examination of several typical applications and installations embodying this principle will further clarify the objectives to be achieved.

Continuous Forming of Viscous Materials. Fig. 7 illustrates a practical application of a high-velocity jet to continuously heat, form, and deliver new products possessing valuable physical characteristics. In this instance, fuel-gas performs a number of precision operations, in proper sequence and with micro-timing. A number of variables are involved that suggest not only the actual complexity of the process but also the many possible combinations of variables to produce new products. These are:

(1) Temperature of the jet;
(2) velocity of the jet;
(3) viscosity of the jet;
(4) temperature-viscosity relation of the raw material;
(5) density of the raw material;
(6) diameter of the raw material entering the jet;
(7) heat transferred to the material in unit time;
(8) rate of raw material fed to the jet;
(9) the relation between the viscous drag of the jet upon the material and its change in dimension and temperature (viscosity) with respect to time).

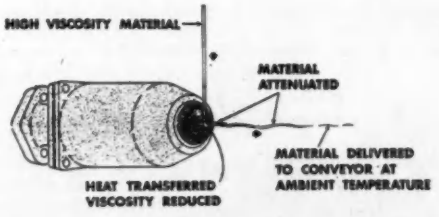

HIGH VISCOSITY MATERIAL
MATERIAL ATTENUATED
MATERIAL DELIVERED TO CONVEYOR AT AMBIENT TEMPERATURE
HEAT TRANSFERRED VISCOSITY REDUCED

Fig. 7. Continuous heating, forming, and conveying of microfine filaments from viscous materials.

Atomisation of Molten Materials. Fig. 8 illustrates the application of a high-temperature high-velocity jet for subdividing molten materials by atomisation. It is physically

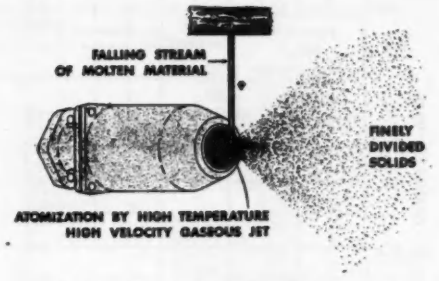


Fig. 8. Atomisation of molten materials.

simpler to shear a liquid than a solid; consequently, many materials of relatively low viscosity in the molten state may be atomised to produce finely-divided solids.

Surface Hardening Automotive Camshaft Cams. Illustrations (in the original paper) show an automatic machine designed to surface-harden the cams of alloy grey-iron automative camshafts. Fuel-gas and air combine in jet-type burners to produce a reproducible, hardenability pattern on each cam surface of the camshaft, simultaneously. The shafts are automatically quenched in oil to produce a hardness of Rockwell C-50. The depth of hardness is illustrated by the metallurgical section shown. The cams are ground in a subsequent operation.

With variable heat balance existing from cam to cam, due to different heat conduction and radiation conditions pertaining to each cam, variable heat-transfer rates must be provided, nozzle to nozzle, by the quadruple nozzle jet burners illustrated. This condition is satisfied by designing the area of the individual nozzles to accommodate the relative heat-transfer rate required by each cam.

The camshafts are charged at the top of the unit where moderate preheat is secured. They are then automatically positioned and rotated—while heat is being transferred to the face of each cam—at sufficient rate to permit surface hardening. The production rate is 120 camshafts per hour and the heat input 1,500,000 B.Th.U. per hour.

Pattern Hardening of Railroad Rail Ends. Another typical application of the jet burner is pattern hardening the ends of T-section railroad rails. One of the factors limiting rail life is 'end batter,' a condition arising from repeated impact of the wheel upon the rail end. Proper hardening of the rail ends to desired mechanical properties has greatly increased the service life of rails, and it appears to be only a matter of time before all rail producers in the United States adopt the method. The pioneering installation was made in the Steelton, Pennsylvania, plant by the Bethlehem Steel Company and illustrations and details are through the courtesy of the Bethlehem organisation.

Sequence

Another illustration in the paper is of an overall view of the rail-end hardening bay. Both ends of the rail are treated simultaneously by indexing beneath burners in the following sequence:

(1) Rail head is heated uniformly to approximately 1,000°F. beneath three unit-type radiant burners for a total time of about 4½ minutes (90 second index);

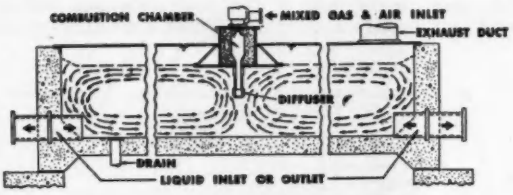
(2) a fourth index places the rail beneath a jet burner, when the burner nozzle is automatically positioned over the rail end: Longitudinally with respect to the rail end, transversely with the rail head width, and vertically for proper clearance between rail head and burner nozzle. Approximately 90 seconds later the desired hardenable temperature pattern appears;

(3) the fifth index accurately positions the rail head beneath the high-pressure air (95-100 lb. per sq. in.) quench nozzle where it is quenched for about 30 seconds;

(4) following completion of the air quench, sufficient heat remains in the adjacent section of the rail head to temper the fine, pearlitic, hardened structure, producing a final

average Brinell hardness well within the range of 331 to 401 as recommended by the American Railway Engineering Association.

At a heat input of 2.5 mill. B.Th.U. per hour per hardening bay, a production rate of over 30 rails per hour, limited only by treatment time and production-line finishing methods, has been attained at one plant.



Typical continuous flow application.

Fig. 9. Submerged direct heating of liquids.

T-rails ranging from 100 to 155 lb. per yard are regularly end-hardened by this method. Production in excess of 500,000 tons of hardened rails by a Pennsylvania plant has indicated a completely satisfactory product.

Precise time-temperature rates (both heating and cooling) permitted the development of a new process.

Submerged Direct Heating of Liquids. Direct heating of liquids is accomplished by the specially designed jet burner illustrated in the paper. Combustion of compressed-air-gas mixture is completed in the refractory-lined combustion chamber under a pressure approximately equal to the submerged hydrostatic head. Gaseous jets of combustion products (near 3,000°F.) issue from the diffuser, creating excellent agitation of the solution, and efficient heat transfer (gases to liquid).

A typical arrangement for continuous flow heating is in the City of Philadelphia's modern sewage-treatment works, where a multiple group of seven burners are used to maintain around the year temperature of sewage sludge at the maximum digestion rate.

One of the products of sewage digestion is a gas of high methane percentage. The gas is collected in digesters (tanks) and piped to air-gas premixture machines from which it is discharged, at a pressure of 3 lb. per sq. in. gauge in stoichiometric proportions, to the burner combustion chambers. Overall thermal efficiency of 85% is regularly achieved and the fuel is a by-product of the basic bacteriological process.

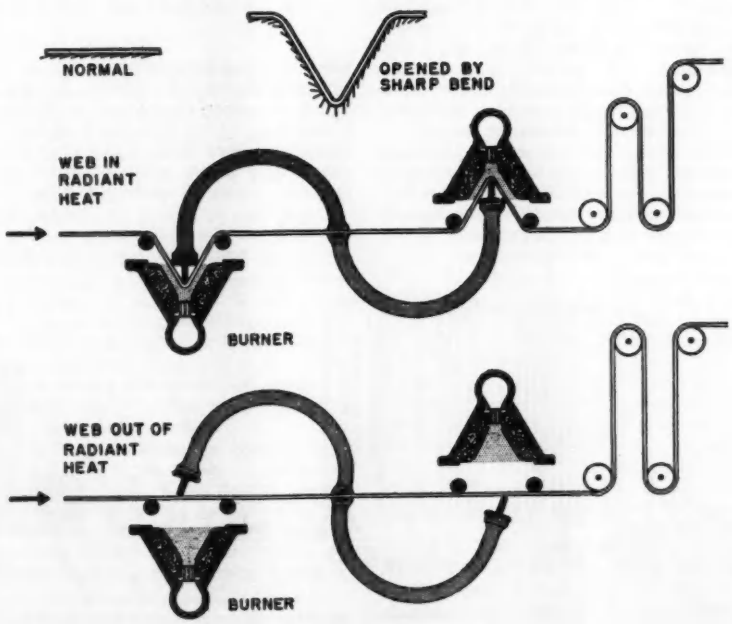
Continuous Singeing of Textiles. Corduroy is singed at 100 yards per minute while passing under the 2 mill. B.Th.U. per hour burner. If the travel of the cloth web is stopped, the cloth automatically retracts from the burner and a heat baffle moves between burner and cloth. Former practice required three passes at much lower speeds to complete the singeing operation.

Fire Polishing of Glass. Electric meter cases are uniformly internally polished immediately after forming. Advantage is taken of the shape of the object and a relatively low-velocity jet type of air-gas burner to achieve beneficial high-temperature gas flow (Fig. 11). The result is uniform heat-transfer over the entire internal area of the object. The fire polishing time is 10 seconds and the heat input 180,000 B.Th.U. per hour.

Continuous Strip Heating. Comparing batch annealing of steel strip to continuous direct-fired radiant heating, the former requires a total heating, soaking, and cooling cycle of about 100 hours, while the latter requires approximately 90 seconds at 1,000 ft. per minute.

Continuous Flow Advantages

The production advantages of a high-speed (1,000 ft. per minute or greater) continuous-flow annealing process compared to a batch process are readily apparent. The fuel economy can be visualised by comparing the two methods of heating and cooling. One of the more important considerations resulting from a new process are the characteristics of the product. The high-speed continuously annealed product has been designated by tin-plate consumers as 'TU' temper (universal temper) because of the different physical characteristics, compared to batch annealed stock. These properties may be summarised as: (1) Uniform physical properties from edge to edge of the strip; (2) a high degree of corrosion resistance due to the elimination of anneal border, which occurs in batch annealed strip; (3) 'TU' temper permits a high degree of drawability when applied to the production of medium and deep-draw products.



b Principles.

Fig. 10. Singeing of textiles.

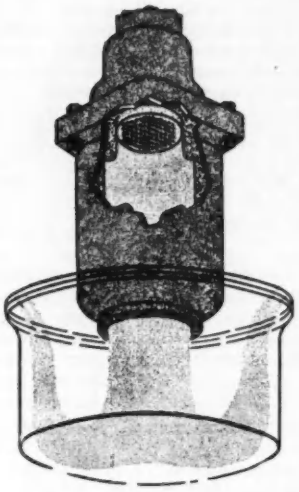


Fig. 11. Fire-polishing of glass.

The tendency of batch-annealed products to flow irregularly around a die is thereby eliminated.

Continuous Heating of Steel Rounds. Heating of round billets for making seamless tubing is a critical operation in the steel industry. Among other requirements the billet must be at uniform temperature—when forced longitudinally over the point in a rotary piercing mill—if uniformity of wall thickness is to be achieved in the final product.

Conventional practices in the steel industry apply roll-down types of furnace and rotary-hearth furnaces requiring about 20 and 15 minutes per in. of diameter to heat to piercing temperature of 2,200-2,250°F. Stationary contact between billet and hearth adversely affects temperature uniformity.

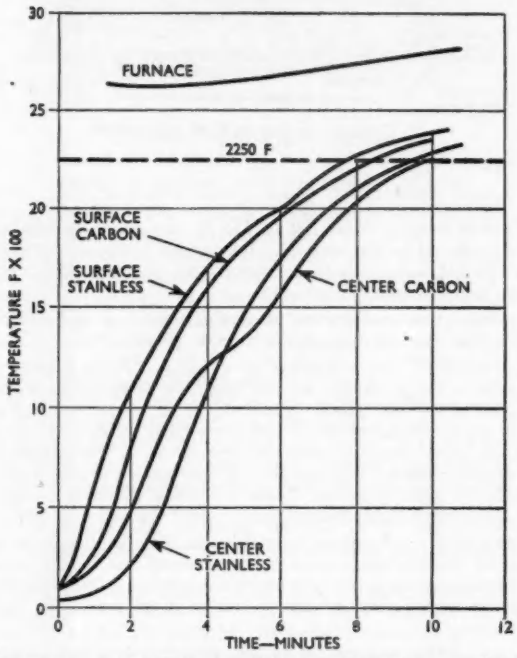
Automatically Cut to Length

High-speed heating, utilising relatively small radiant enclosures completely surrounding the billets, is arranged to provide the tonnage required when heating at a rate of 4 minutes per in. of diameter. An installation for heating a maximum of 40 tons per hour is illustrated in the paper. Billets approximately 30 ft. long and 4-5 in. in diameter are charged and conveyed automatically through the heating zones. The billets are automatically cut to length at 2,200-2,250°F. by a hot saw and delivered to the piercer.

The principal advantages gained by this heating method are: (1) A constant supply of uniformly heated rounds to the rotary piercing mill; a necessary starting point toward the production of concentrically uniform seamless tubing; (2) reduction in scale per heated ton owing to reduction in heating time; (3) reduction of power required to displace the metal at the piercer owing to improved plasticity of the uniformly heated round; and (4) reduction in operating personnel owing to adaptability of the design to automation.

Tubular products are similarly heated on an individual, continuous, high-temperature-gradient basis in order to perform the operations of: (1) Re-heating for sizing; (2) hardening; (3) tempering; (4) annealing; (5) normalising.

Fluid Processing in the Petro-chemical Industry. A tubular heater illustrated has greatly extended the on-stream operating time in refinery operations. A schematic diagram of the heater shows radiant burners, distributed and zoned in opposing side walls, exposing the tubes to direct radiation from both sides and to low-velocity uniform-temperature combustion products.

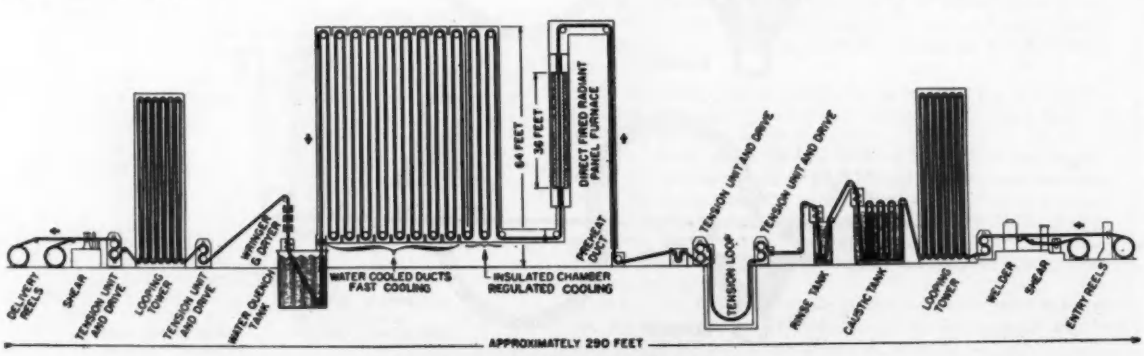


Heating rates for 4-inch round billets in barrel-type gas-fired furnace of heat input 2,840,000 BThU per hr

Fig. 13. Continuous radiant heating of steel rounds.

Complex time-temperature curves are readily obtained in the radiant section of the heater. Localised overheating is eliminated, permitting heater duty to be increased to the maximum permissible for the alloy tubes or for the liquid under process. Results obtained during three years operating experience show conclusively higher yields of higher quality products without the introduction of costly operating problems.

Direct-fired Dryers in the Printing Industry. Another illustration is of the application of two retractable-web radiant dryers to a single web, four-colour perfecting web press. Web



Flow diagram for high-speed strip annealing.

Fig. 12. Radiant-burner direct-fired continuous heating of strip.

speeds of 1,200-1,600 ft. per minute are in common practice today, producing 20,000 magazines per hour per press.

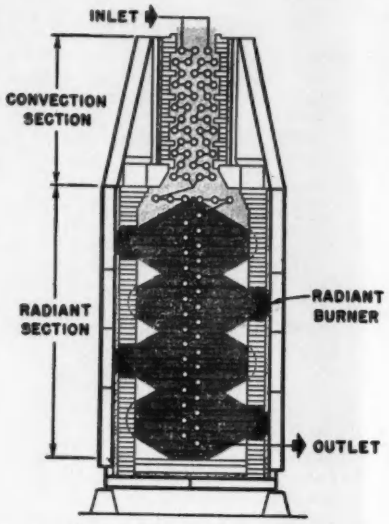


Fig. 14. Radiant heating in the petroleum industry.

Control of web speed, temperature head, and temperature uniformity in micro amounts permits of 'setting' the ink without discolouring the paper or impairing the fidelity of the colours.

New processes, new products, and improved existing processes will result from more tightly coupled knowledge among the fields of process development, combustion, heat transfer, and fluid mechanics. Relatively little information is available on the subject of high-temperature aerodynamics, but it is as fundamental to heat processing technology as the combustion reaction itself. It is hoped that this paper has succeeded in pointing clearly to the more important objectives. By citing actual applications of these principles perhaps the imagination of industry will be stimulated toward further progress in heat processing.

APPENDIX

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From a paper to the Midland Junior Gas Association, March 28, 1950.

Moulded Refractory Burners for Tunnels for Industrial Purposes

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THIS paper gives an account of the design, construction, and performance of a special type of moulded refractory burner to be used for local heating in industrial operations. The burner consists of a short converging tunnel at the base of which theoretical air/gas mixtures are burnt. The flames are formed at the mouth of a series of slots in the base of the tunnel, which base is moulded integral with the tunnel walls. The performance of these burners is gauged by the heat imparted to a circular water tube across the tunnel mouth, and the results are related to standard data on forced convection.

In industrial operations occasions are often arising where local heating of a component is required. Such heating may take the form of a fusion as in glass manipulation or silver soldering, local softening or annealing as in metal fabrication, or heating prior to local hardening. Of necessity the Birmingham undertaking has always had a keen interest in this work and papers† have been read by other members of the staff to throw considerable light on the subject.

The present work originated as the result of requests from two manufacturers who required what we may call 'contoured' flames for certain fusing operations. The burner system adopted after many attempts had some very good features and though it resembles in some characteristics other forms of local heating burner, there are some aspects of its manufacture and performance that are worth attention. Accordingly, though its ultimate form is not yet decided, it is considered that the time is opportune to present an account of it to those interested in industrial burners.

It is not proposed to review other types of contact burners, descriptions of which will be found in the papers referred to. References will be made to them as points of comparison arise.

The factors which influence the success of a burner for local heating may be considered under the following headings:—

1. The shape, size, and position of the flame.
2. The temperature of the flame and the ready reproducibility of the flame characteristics.
3. The velocity of the products of combustion as affecting the rate of heat transfer by forced convection.
4. Other factors: performance of burner, silence, flameproofness.

For a flame to be so disposed to the surface or edge to be heated that it is used to the best advantage demands a burner designed for each particular purpose (as the one I propose to discuss) or a burner which can be built up from a number of sections, as certain strip burners available, or a number of small units suitably placed.

Our early attempts to make a contoured burner were in the nature of converging tunnel burners fired by a drilled mixture manifold at the back. Owing to a lack of uniformity in the flame this was discarded in favour of a refractory grid, moulded for convenience with slits and not with circular holes. This was later superseded by the present design with walls moulded integral with the grid.

The converging burner tunnel in which combustion takes place is formed in a refractory block which constitutes one

† J. Palser. The Concentrated Combustion Burner, M.J.G.A., November, 1945.
J. F. Wright and J. Palser. Furnaceless Heating. *Industrial Gas*, March, 1947.
J. F. Waight, M.J.G.A., March, 1949. *Industrial Gas*, November, 1949.

boundary of the mixture manifold, the other boundary being the welded steel box in which the block is rigidly retained. Air/gas mixture from a suitable mixing device passes to the tunnel proper through a series of properly proportioned slits, connecting manifold and tunnel, and there burns to give a very hot and rapid stream of products of combustion which may be accurately directed from the tunnel mouth on to the work to be heated.

Before I describe to you the operation of making such a burner system I should say that in the early days of our work on these problems our attention was drawn to the possibilities of silicon esters as bonding material for high grade refractory special shapes, and our technique of moulding proceeded concurrently with that of burner design.

The silicon esters as available commercially have the composition Si $(OC_2H_5)_4$ and they can be hydrolysed—*i.e.*, caused to react with water to produce a silica gel which, if dispersed among suitable refractory grains, can be dried and fired to give a very strong bond. The hydrolysis is effected by mixing with the ester a water-alcohol mixture, the water content of which can be varied within limits, to control the process of hydrolysis and rate of setting. Various refractories may be used—*e.g.*, sillimanite, zirconia, alumina, &c., subject to suitable nature and size of grains. For success the grains must not be rounded but sub-angular, and a mixture of small and large should be used. We have used throughout sillimanite grains of mesh −30 +80 and sillimanite flour, which gives very sharp mouldings—a necessity when fine orifices are to be formed.

Moulding Operation

A wooden core corresponding to the desired tunnel shape is pinned, mouth down, to a flat base plate, and on its ½ in. wide upper surface a series of shallow slots is cut with a hack saw, at specified distances, to take fins to form the combustion slits. These fins are of stiff card or plastic of correct gauge and guillotined to size ½ in. by 1¼ in. Over this tunnel core is clamped the burner box with back removed and with its front edge lined with H.T.I. brick, so sized as to come within ½ in. on every side of the projected tunnel mouth. The H.T.I. is closely fitted and cemented into position and moreover retained at the sides by strips of iron pinned to the sides of the box. Into this mould thus formed the correct amount of sillimanite, ester, and alcohol mixture is poured, to cover the fins to within ¼ in. of the top, vibrated to fluidise and consolidate the mass, allowed to set, dried, and fired to about 700°C. After blowing out the ash and generally cleaning up, the back is sealed into position and the burner ready for use.

The size and separation of the slots to be formed in the base of the tunnel were originally founded on the consideration that with relatively large manifolds the burner should be flameproof. Limiting diameters for circular holes to prevent light back in theoretical mixtures should be of the order of 1.8 mm. (0.071 in.). In point of fact, about half this width is essential. Other considerations, however, require the slot width to be 0.020 in. or less, so that these burners are well within the flameproof limit.

The ratio of slot area to base of tunnel is based on the relative volumes of unburnt gas and expanded products of combustion, so that for slots of 0.020 in. width the spacing required is 7.5 to the inch (practical ½ in. centres). The tunnel base has, from strength considerations, been kept at ½ in. wide. The tunnel length and aperture depend on the concentration and required dimension of flame, and will be considered under the heading of velocity of products of combustion.

Optimum Flame Conditions

The next consideration is that of getting optimum operating conditions—*i.e.*, of regulating air and gas to give maximum flame temperature which corresponds in a practical sense to theoretical proportions of gas and air.

For the tests and regulation of this burner we have availed ourselves freely of a device due to Brinsley and described in a recent paper* to the Institution of Gas Engineers. Known as the calyx flame this device is such as to give a degree of precision to manifold burner adjustments which could not be obtained by any other means, and in fact is invaluable for both laboratory and district work. For example, reference to Table 2 shows five independent adjustments of gas rate to a standard air setting for five different venturis, fitted to the air entrainment device and indicates the exactness with which the adjustments can be made.

The calyx burner is fed by a bleed from the air-gas manifold and the mixture flame is caused to burn in its own products of combustion, with rigorous exclusion of extraneous air. If in the mixture there is air in excess of that required for combustion, then no violet calyx is formed at the base of the flame, but immediately on reaching theoretical mixture proportions a calyx appears and intensifies in colour on further enrichment with gas.

Using, as will be described later, a small water cooled tube in the flame as an indication of heat transfer, a series of tests was made with a small moulded burner with a constant air flow and variation of the gas entrained. The results are given in Table 1.

These figures show that for over-aerated conditions the heat transfer is not unduly affected by excess of air. With excess of gas, however, heat transfer rapidly falls off once calyx conditions are passed. When heating a hot body, however, a different result will be obtained on account of the serious diminution in temperature difference. In practice with brazing tests it has been found that much the best results are obtained when strict attention is paid to the regulation of the burner. For all tests, therefore, calyx adjustment was used.

The burner, being of a manifold type fed by an injector, is capable of use by entraining air at atmospheric pressure, giving constant proportioning of mixture and reproducibility of mixture and flame characteristic.

Even with the hottest flame suitably disposed to the work it may still be necessary to use the maximum velocity of products of combustion—*e.g.*, in local heating of metals where thermal conductivity is so important, speed of heating is essential. Or again it may be necessary to make the best use of available air pressure. We must, therefore, examine the problem of producing maximum velocity of products of combustion on to the work. This velocity will all have its origin in the energy of the air jet which energy will appear partly as static pressure in the manifold and static pressure at the base of the tunnel which latter pressure accelerates the gases towards the mouth when the tunnel is convergent. The conditions for the successful accomplishment of this energy conversion have been laid down in a paper already referred to and the results given

* Brinsley—June Research Meeting. Inst.Gas E. Gas Heat in Industry August, 1949.

TABLE 1

Aeration condition	Gas flow cu. ft. per hour	B.Th.U. per hour measured	B.Th.U. per thous. sq. ft. per hour	B.Th.U. per thous. sq. ft. per hour per cu. ft. of gas
Over aerated, no calyx	66·5	875	312	4·7
—ditto—	70·6	992	354	5·0
—ditto—	75·9	1061	379	5·0
Faint calyx	78·5	1095	391	5·0
Pronounced calyx	80·7	1073	383	4·75
—ditto—	81·5	940	334	4·1
—ditto—	88·5	955	340	3·84

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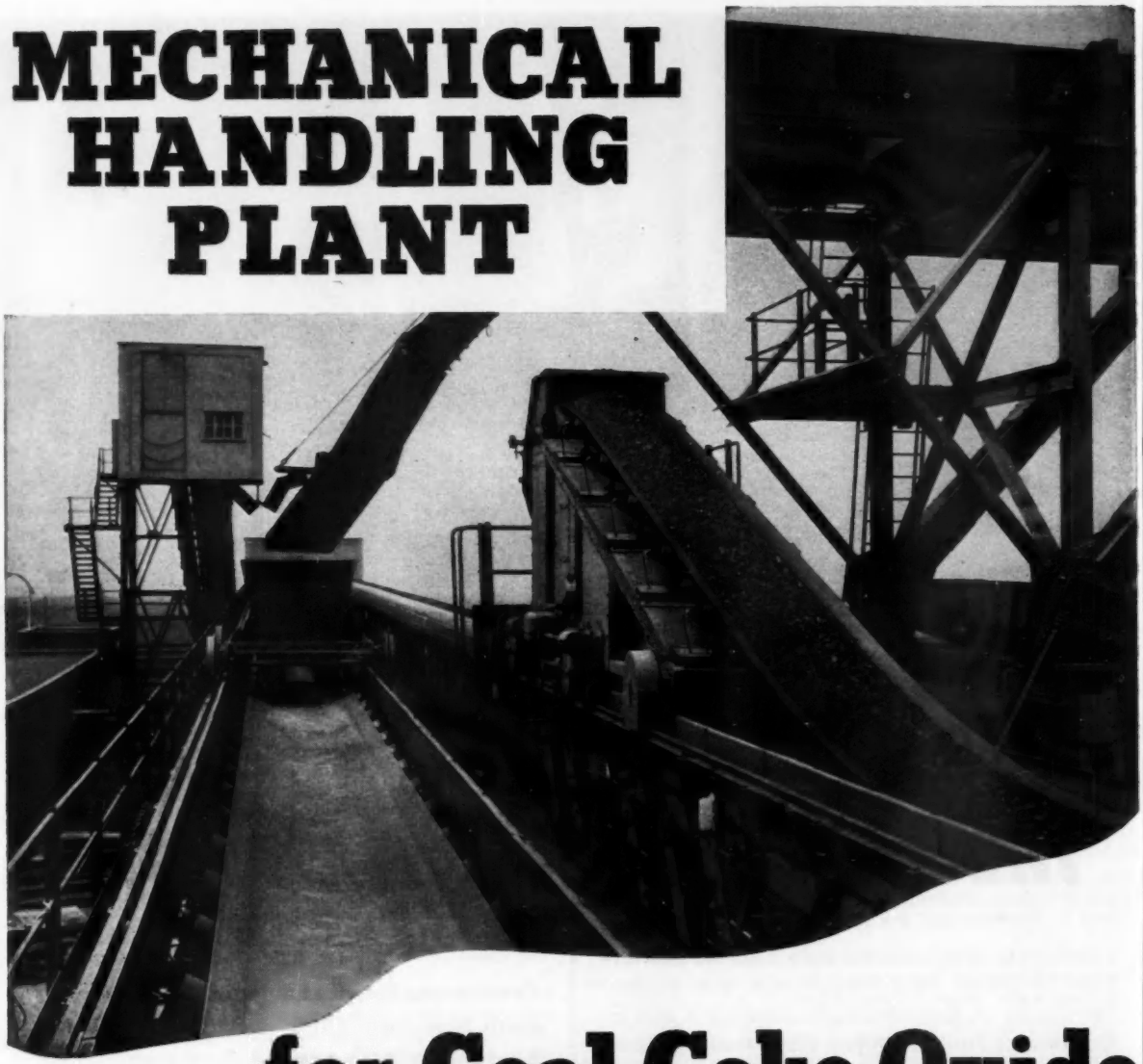

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TABLE II. Tests to determine optimum diameter of venturi for use with a given burner and corresponding pressure and flow relations.

Air jet dia. in. d.	Venturi throat dia. in. D	Ratio $\frac{D}{d}$	Gas pressure in. W.G.	Manifold pressure in. W.G.	Gas rate cu. ft. per hour	Suction at point of entrainment	Condition gas and air full on
0·241	·281	1·17	3	7·7	126	− 6·9	overgassed
	·312	1·29	3	8·4	131	−12·4	,,
	·336	1·39	3	8·4	132	−12·5	,,
	·360	1·49	3	8·2	128	− 9·75	,,
	·385	1·60	3	8·0	127	− 8·05	,,
	·281	1·17	0	8·0	127	− 6·9	,,
0·281	·281	1·00	3	12·4	164	− 1·5	,,
	·312	1·11	3	13·15	171	− 4·4	,,
	·336	1·20	3	13·15	171	− 5·2	,,
	·360	1·28	3	13·0	169	− 4·65	,,
	·385	1·37	3	12·95	168	− 3·7	,,
	·385	1·37	0	12·95	168	− 3·7	,,
0·306	·281	0·92	3	14·4	170	+ 2·4	no calyx
	·312	1·02	3	15·3	188	+ 0·5	overgassed
	·336	1·10	3	16·0	193	− 2·1	,,
	·360	1·18	3	15·9	192	− 1·6	,,
	·385	1·26	3	15·6	189	− 0·9	,,
0·320	·336	1·05	3	16·7	199	+ 1·5	,,
	·360	1·12	3	17·0	202	+ 1·3	,,
	·385	1·20	3	17·0	200	+ 0·5	,,

form a very satisfactory confirmation. I am giving in Table 2 a number of sections of a complete test of a burner system which could be fitted with five sizes of venturi and in which the air jet was increased progressively in stages.

Burner dimensions:

Mouth 3 in. × ¼ in.
Slots 17 × 0.024 × ½ in. of area 0.204 sq. in.

The following points are of importance:—

1. In each series of tests venturi No. 3 gives the maximum manifold pressure and maximum gas rate corresponding to calyx conditions. For this optimum size of venturi the ratio of throat area to port area was 0.435 in.
2. As the size of this jet is increased and the ratio of the diameter of the venturi to that of the air jet approaches 1.1, so maximum manifold pressure and gas flow are developed.
3. Within the size limits laid down above automatic proportioning due to governing to atmospheric pressure is possible.
4. It is worthy of note that the maximum manifold pressure corresponding to 40.8 in. W.G., air pressure is 17.0 in. W.G. which corresponds to 42% conversion. This serves as a guide to the efficiency of energy conversion.

These data lay down, for our gas, the approximate proportions of an injection system and burner, but are subject to certain limitations.

Restricting the Escape

The effective aperture of the burner is not that of the slots alone for the resistance of the tunnel beyond these slots also has an effect on restricting the escape from the manifold. In fact the pressure developed at the base of the tunnel is fairly considerable, as the following figures for a tunnel of taper 21° (included angle) would show.

Air pressure, in. W.G.	6.8	13.9	26.2	56.1	111.2
Manifold ,, ,, ,,	3.5	5.6	9.7	17.7	30.4
Tunnel ,, ,, ,,	0.5	0.8	2.1	4.3	7.7

From these figures it would follow that the ratio of possible discharge without tunnel, to that obtained with the tunnel, is 1 to 0.93 for the lower air pressures. In other words for this very convergent tunnel the tunnel is equivalent to a reduction in grid size of 7-13% according to the air pressure. For most purposes, therefore, this correction can be neglected.

It might be noted at this point that the discharge coefficient of the slots varies from 0.37 to 0.5, which is the result of a temperature effect, the mixture tending to heat up at low rates of throughput.

To make the most efficient entraining device for a high velocity burner the following size relations must hold:—

Tunnel length (in.) × ½ in. = tunnel base (sq./in.).
Tunnel base (sq. in.)/6.8 = slot area (sq./in.).
Slot area × 0.45 = venturi area giving venturi dia. D.
D/1.1 = air jet diameter.

If a low velocity burner is being made, then a proprietary make of injector approximating to the above, may be fitted.

In the early stages of the development of this burner we had little to guide us in the matter of optimum tunnel shape. The object of the burner being at times to use the greatest velocity locally, it was realised that we could effect this by making the tunnel more convergent, but quantitative measurement of the effects produced was not forthcoming until we adopted the simple technique of using a water cooled tube across the burner mouth as an index of heat transfer.

The tube used for these tests was of polished heat resisting steel 0.126 in. outside diameter and 1/16 in. inside diameter. A suitable length of this was soldered into two brass bushes which could be screwed into ⅜ in. tee pieces with accommodation for a suitable accurate thermometer and appropriate connections for water inlet and outlet. The inlet was connected to a constant head tank and the flow of 1 lb./min. gave a suitable temperature rise with all burners. It was established first of all that within reasonable distance of the burner mouth consistent results of heat transfer could be registered. Thus with a 2 in. by ¼ in. slot burner working at 48 cu.ft. per hour the following data were observed:—

Distance of tube above burner mouth... ...	⅛ in.	¼ in.	⅜ in.	½ in.	⅝ in.	¾ in.
Heat transfer. B.Th.U. per hour registered ...	1,550	1,555	1,550	1,450	1,340	1,175

In all tests, however, the distance from the burner mouth was standardised at ¼ in.

The fact that the burner orifice is ideally suited to heating a tube is of great importance because it enables us to calculate

the amount of heat transferred by forced convection during any test. The total quanity of heat transfer (convection and radiation) being accurately determined, the radiant heat transfer follows by difference.

A great deal of work has been performed on the heating of circular section tubes in streams of hot fluids (liquids and gases) and all the data for widely differing conditions of temperature difference, tube diameter, velocity of fluid, and fluid characteristics can be related to each other by an expression of the form.

$$\frac{Hd}{k\theta} \Big/ \left(\frac{c\mu}{k}\right)^{0.3} = \left(\frac{dv}{\mu}\right)^{0.6}$$

This applies to high velocity streams where $\frac{dv}{\mu}$ the Reynolds number has a magnitude greater than 1,000.

In this formula the symbols represent:

- h = heat transfer in B.Th.U. per sq. ft. of tube surface per hour.
- d = tube diameter (ft.).
- θ = temperature difference between fluid and tube °F.
- v = mass velocity, *i.e.*, lb. fluid per hour per sq. ft. of burner aperture.
- c = specific heat at constant volume.
- μ = viscosity of fluid.
- k = thermal conductivity of fluid.

$c\mu$ and k are obtained from standard data on gases and the value $\frac{c\mu}{k}$ which appears in the formula is taken as constant at all temperatures. These data are obtained for the mean temperature of the film between fluid and solid.

The mass velocity of the fluid is obtained from the gas rate, theoretical air requirement, and burner orifice. For a calculation of h therefore, it is necessary to determine the flame temperature or assume a reasonable value for same. The determination not being possible it was decided to adopt a figure of 1,850°C. for the flame temperature. Recent results by Leason* working with similar types of converging tunnels indicated flame temperature of this order. In the event of this temperature being, say, 100°C. too high, then the error introduced with a calculation of convection to tube at 30°C. would be approximately 6%.

First Application

In our early work on this type of burner we had remarked on its curious behaviour with increasing mixture feed. Thus a burner working at a low air pressure of ½ lb. per sq. in. would have the tunnel walls at a temperature of perhaps 1,250°, but on increasing the air pressure and gas consumption to retain calyx conditions the temperature of the tunnel fell and finally became relatively cold. Reference to Section 1, Table 3, illustrates this.

Our first application of heat transfer measurement was to determine the cause of this and a series of tests was performed with a 2 in. by ¼ in. slot burner of which the grid had 11 slots ½ in. by 0.025 in. The heat transfer performance is set out in Table 3, Section 1. We note that the heat transfer rises sharply to a definite maximum at 40,000 B.Th.U. per hour input, after which further increase of mixture feed leads to no appreciable increase in heat transfer. This phenomenon, which indicates a reduction in flame temperature, has been ascribed by Leason to turbulence at the point of combustion. At the point of maximum heat output which will correspond to fully turbulent conditions in the cold mixture stream the Reynolds number has a value of 3,070. There is a definite change in direction at a heat input of 24,000 B.Th.U. at a Reynolds number of 2,000. These figures are a good indication that turbulence is playing a big part. Moreover the following tests tend in the same direction. It was decided to make some burners with narrower slots,

* Leason. University of Leeds Library. Private Communication.

TABLE 3. HEATING PERFORMANCE OF SLOT BURNERS

Burner	Grid slots	Gas rate cu. ft. per hour	Heat transfer observed B.Th.U. per sq. ft. per hour (thous.)	Heat transfer convected calculated B.Th.U. per sq. ft. per hour (thous.)	Heat radiated B.Th.U. per sq. ft. per hour diff. (thous.)	% of total heat radiated	Tunnel wall temperature °C.
Section 1. 1 in. long tunnel taper ¼ in. to 0·142 in.	0·5 in. × 0·025 in.	30	215	155	60	28	1240
		50	282	199	83	29·4	1290
		63	315	224	91	28·8	1250
		78	345	238	107	31·0	1180
		96	363	270	93	25·6	1080
		112	356	296	60	16·9	patchy
		138	358	335	23	6·4	,,
		174	360	385	−25	—	cool
Section 2. 1 in. long tunnel taper ½ in. to 0·264 in.	0·5 in. × 0·017 in.	40	200	125	75	37·5	1160
		58	242	155	87	36	1260
		81	287	186	101	35·2	1310
		111	345	218	127	36·8	1260
		135	386	228	158	40·9	1260
		155	417	248	169	40·5	1200
		175	433	266	167	38·6	—
Section 3. 1½ in. long tunnel taper ½ in. to 0·16 in.	0·5 in. × 0·017 in.	36	222	160	62	28·0	1240
		54	282	194	88	31·2	1320
		77	342	234	108	31·4	1380
		111	408	274	134	32·8	1380
		132	438	304	134	30·6	1440
		177	516	362	154	29·8	1430
		225	576	422	154	26·7	1440

Fig. 2. Nomogram for calculating theoretical jet velocities

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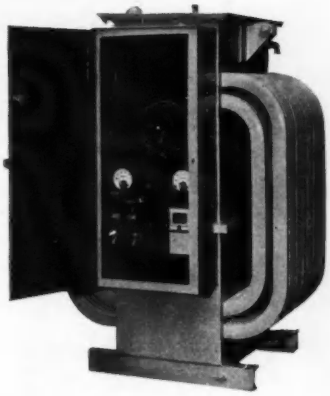

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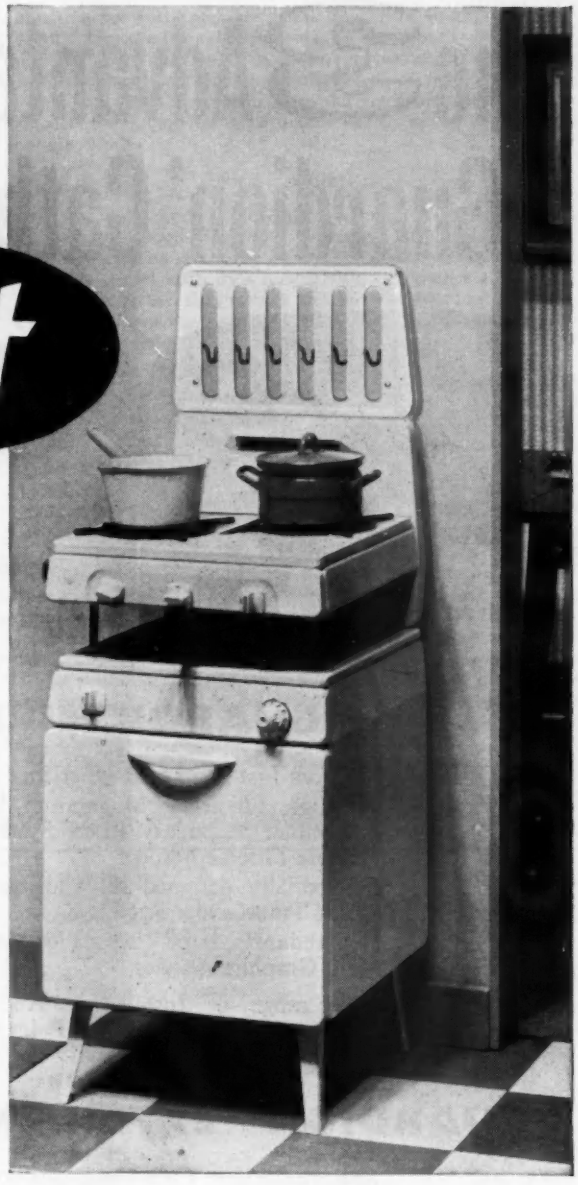

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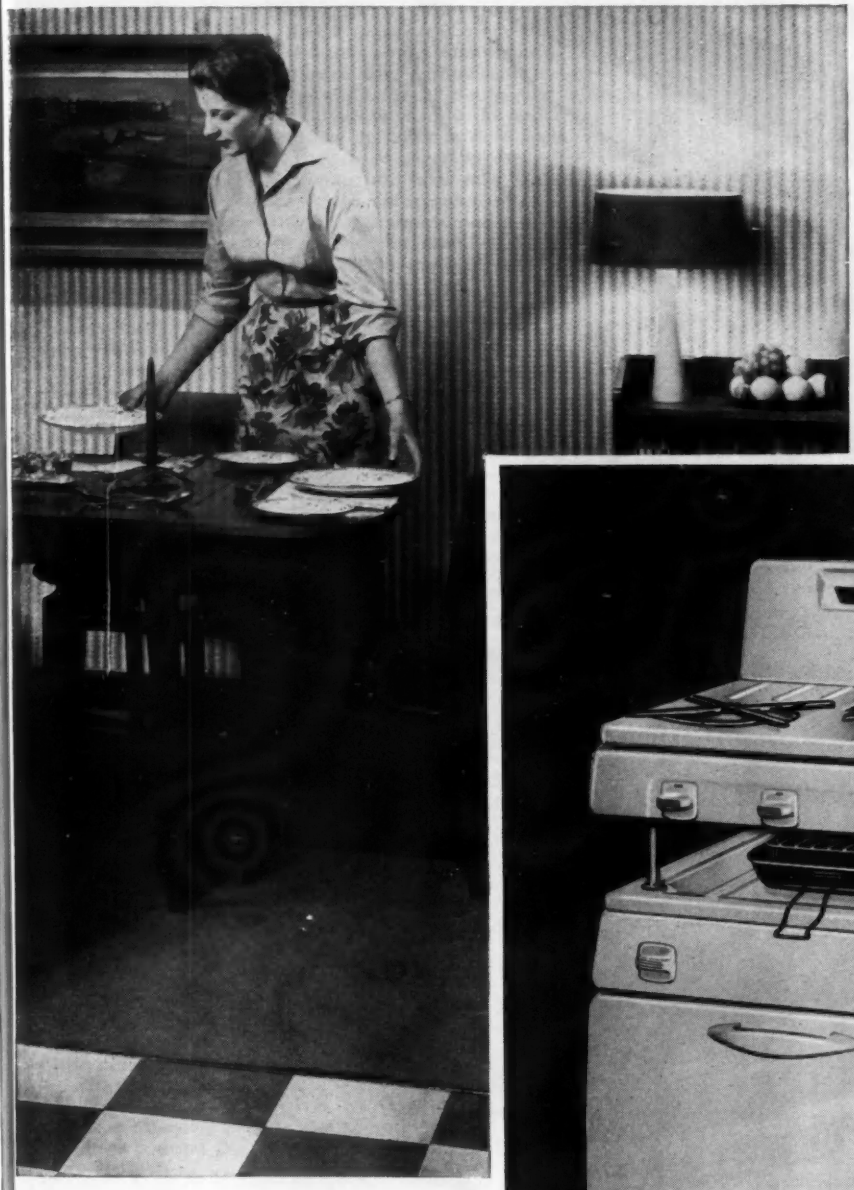

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keeping the burner port constant and so to get mixture flows of lower Reynolds number. Two burners were constructed with slots of width 0.017 in. and 0.008 in., the latter being a strip metal grid. The results of tests on these burners certainly show considerable increases in the capacities of the burners with diminishing width of slot. Turbulence due to slot width may not be the only disturbing factor at higher mixture feeds, but tunnel convergence may be playing an important part.

It had formerly been noted that with large slots discharging into a small taper tunnel that the phenomenon of maximum heat delivery had been observed, but we had not tried a small taper tunnel with small slots. This was, therefore, done next, and in Section 2 of Table 3 the results are given to show little indications of change in direction, and in fact its performance eventually equals that of the narrower tunnel B with its greater mass velocity. In the case of the wider mouth tunnel a greater proportion of the heat is transmitted by radiation. There are thus grounds for supposing that tunnels of smaller taper would be an advantage and it was decided to make a tunnel of taper 14° included angle and get a mass velocity at the mouth equal to burners A, B, and C by extending the length of the tunnel to 1½ in. The results are given in Section 3, Table 3.

It should be noted that the slots were 0.020 in. width so that a considerable improvement is shown by making the tunnel taper less. The change of cross-section due to a 14° included angle on a straight tunnel corresponds to that due to a 7° included angle on a circular section and is, therefore, in harmony with general practice. With small taper tunnels there does not seem to be much point in making the slots less than 0.020 in.

Of the various burners constructed we may regard the performance of that marked E as typical and summarise it as follows:—

Air pressure, lb. per sq. in.	½	1	2	3
Gas consumption, cu.ft. per in. length of tunnel	27	39	55	66
Gas rate, cu.ft. per sq. in. tunnel aperture for ¼ in. wide tunnel	216	312	440	528
B.Th.U. developed per cu.ft. of tunnel space—mill.	40	58	82	98

One of the most important considerations is the life of the refractories. As regards the tunnel walls the temperature will be shown in Table 3 varying with rate of working but is well within the scope of the high grade sillimanite used. The slotted grid is at a much lower temperature and trouble is not anticipated here. Burners have been in use (40 hours per week) for a year under rather disadvantageous conditions with very encouraging results. Some readily replaceable unit construction which could be pre-fired and cemented into position as required, seems to be called for.

Coupled with this question of life is that of the strength of the refractory block. For low pressure working up to 2 or 3 lb. there seems to be little doubt (though it has not been made the subject of test) that the refractory is strong enough. For high pressure working extra support of the refractory, with possibly a metal grid, may be required.

The Question of Noise

Another important consideration, especially where the burner has to be tended, is that of noise. At low ratings, up to 2 lb. air pressure, the burner would be regarded as quiet. Above about 4 lb. air pressure the noise would not generally be permissible.

A number of burners have been supplied or are on order for the silver soldering of components of oil lamps. Such operations require the precision and shape of the flame more than intensity other than that of correct mixture adjustment. Air pressures of 1 lb. per sq. in. are adequate. With such small tubular and pressed assemblies mounted on a turntable and 2 in. slot burners directed across the work, fusion times of 40 to 60 seconds are attainable. A fair degree of overheating is found to be possible, a component fused at 40 seconds being unharmed by 60 seconds heating so that with proper attention wastage should be reduced, the process can be fully mechanised or left to individual attention.

A brass boss to be soldered to the centre of a ¼ in. brass tube by two silver solder rings required 50 seconds for the first ring and 10 seconds for the second on rotation into position. The total gas consumption for the two burners required was 50 cu.ft. per hour. Semi-skilled labour could be employed.

A firm of manufacturers of steel blades required a local softening of a narrow strip 2 in. by ¼ in. wide across the handle —a time of 18 seconds not to be exceeded. A time of 15 seconds was attainable, the gas consumption for the burner being 100 cu.ft. per hour.

Experiments are on hand for the local hardening of two cutting edges of special cutter blades of section about 1 in. by ¼ in. This relatively heavy section requires about 80-95 seconds for bringing the edges to hardening temperature at 1½ lb. air pressure.

Edge Fusion of Glassware

A great deal of experimental work has been performed on edge fusion of glassware for which the burner was originally devised. This work is still in hand.

It is felt that this burner is capable, perhaps in a somewhat restricted field, of rendering some very good service in industrial heating. The essential features of its design have been established by the means described and its performance coincides with the maximum effort of which forced convection, assisted by radiation, is possible. Though simple in outline it yet remains for us to put its construction on a really sound basis.

Standard for Underground Copper Tubes

THE revised British Standard for copper tubes to be buried underground (B.S. 1386:1957), provides for tubes having the same applications as those dealt with in the 1947 edition. Thus they are suitable for connection by means of compression fittings, or capillary fittings or by bronze or autogenous welding, and are of the type to be buried underground for the conveyance of water, town gas etc.

The value of the maximum tensile strength for annealed tubes and the minimum tensile strength for as-drawn tubes has been reduced from 17 tons per sq. in. to 16.5 tons per sq. in., and the angle of drift has been amended to 45° (the angle now being adopted in all British Standards for copper and copper alloy tubes).

Other amendments are a modification of the 'freedom from defects' clause to ensure that deleterious films are not present in the bore of the tube; and a clause which specifies marking with bands of adhesive tape indicating the number of the standard and temper of the tubes supplied, as well as permanent marking of the tubes with the supplier's identification mark.

As in the previous edition, tubes are standardised on the basis of outside diameter; this means that the outside diameter selected for each size is that laid down in B.S.659:1955, one wall thickness being recognised as standard for each nominal size.

Also as in the previous edition, two grades of copper are specified complying with B.S. 1172 and B.S. 1174, but by using the designations C106 and C107 they have been further identified with the corresponding alloys in the schedule of copper and copper alloy tubes (B.S.2871).

Copies of this Standard may be obtained from the British Standards Institution, Sales Branch, 2, Park Street, London, W.1. price 3s.

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Sales of more than a million copies of British Standards, and new issues bringing the total number of current standards to over 3,000 are among the achievements recorded in the annual report of the British Standards Institution for the year ended March 31, 1957, which was presented to the Institution's members at the annual meeting yesterday. The number of subscribing members supporting the Institution—over 9,000—is also the highest yet reached.

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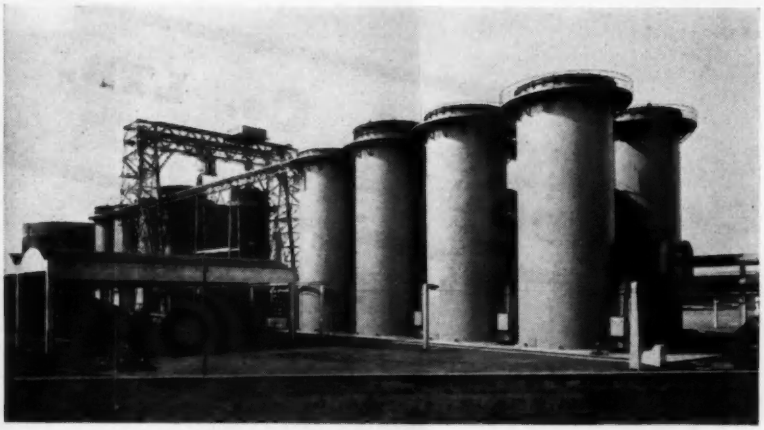

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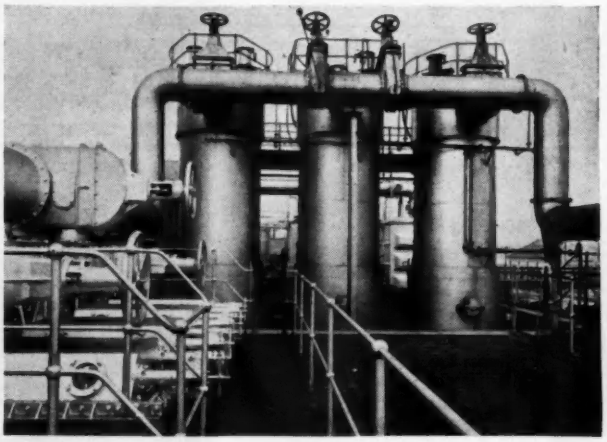

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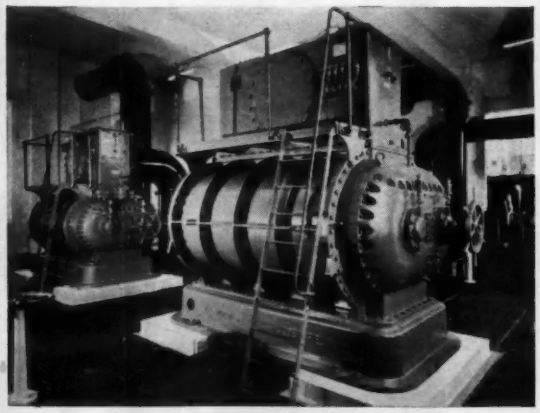

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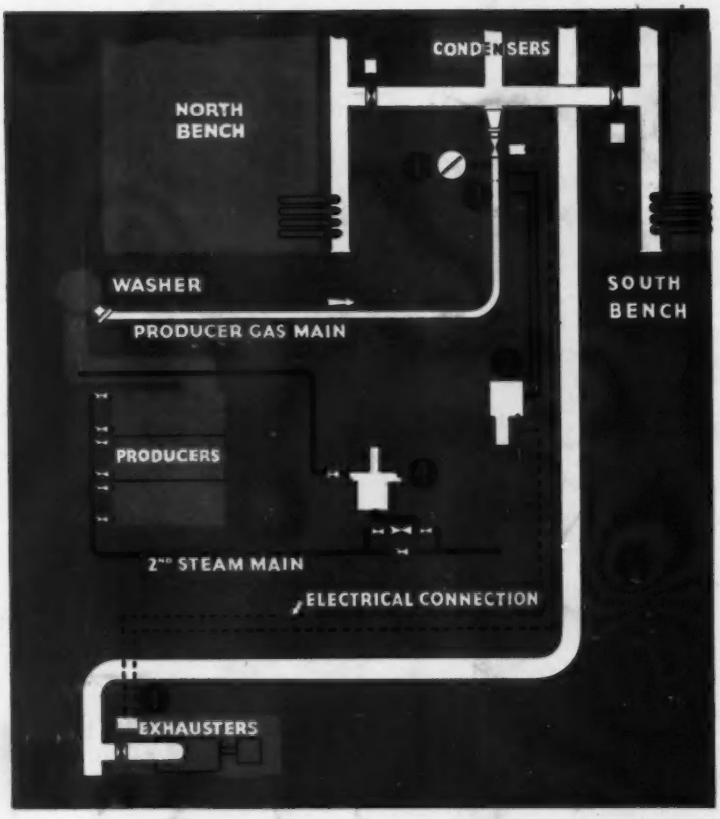
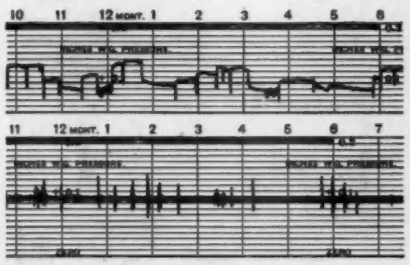


At the Ponders End Works, Tottenham Division, Eastern Gas Board, raw gas from two I.V.C. benches is diluted by approximately 50 B.Th.U., by washed producer gas. The diluent gas is introduced before the primary condensers via a motorised proportioning valve. The valve is operated remotely by push button controls about 400 feet away. Here the C.V. trend is observed on a nearby calorimeter connected at inlet to benzole plant.

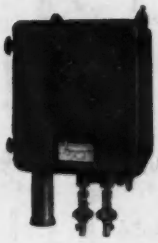
An Electroflo ring balance, transmitting flow meter is installed near the producer gas valve. Diluent flow rate indicators are situated in the exhauster house, and at the valve itself which can be manually operated in the case of electrical failure.

Venturi steam to the diluent producers is automatically controlled by a series 55 oil-operated regulator to maintain constant offtake pressure conditions.



Diluent producers offtake pressure records. The lower chart shows the effect of automatic control of Venturi steam.

1. 12" DIA. INDICATORS show flow rate of diluent under remote control.



2. RING BALANCE GAS FLOW TRANSMITTER and orifice plate, **3**, in diluent main operating flow indicators as above.

4. SERIES 55 OFFTAKE REGULATOR automatically controlling Venturi steam to diluent producers.

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